FISH IN NUTRITION

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NUTRITION

Edited by

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PREFACE

DURING the past ten years FAO has devoted considerable time, energy and expenditure to the study of the world's fishery resources and to the problem of how best to exploit and utilize them. Its Fisheries Division has promoted a number of useful studies and published their results in a series of books.

The present volume is the outcome of an FAO Conference on "Fish in Nutrition" held in Washington in September 1961. This Conference, as the title indicates, had a broader scope than any previous one, inasmuch as its theme included the study of human nutrition as well as animal nutrition.

The Conference, which was attended by about three hundred participants from many countries, aroused keen interest throughout the world. Seventy papers were submitted by experts from twenty-four nations, and the majority of those attending took part in the discussion. I believe that the information thus collected is of such value that it should be made available to a wider public. With this end in view, the proceedings of the Conference are now being published in the form of this book.

The Conference, among other things, focused attention on the problems of human nutrition the urgency of which has been brought to the fore through the Freedom from Hunger Campaign. A large proportion of the world's population suffer from varying degrees of malnutrition. Protein deficiency is one of the major causes of malnutrition, and it is obvious that fish, a protein-rich food, could be an important factor in reducing the incidence of malnutrition. Yet, the present harvest of fish is still below 40 million metric tons, that is, less than one per cent of the total world food production. It would seem then that quantitatively fish plays a negligible part in the world's food supply, a situation that lends itself to vast improvement through a more rationalized exploitation of the resources of the sea for providing human nutrition.

It would be appropriate here to recall the message which was sent to the Conference by President Kennedy. He said: "A first responsibility of the human race is to see that its members have enough to eat. . . . Nutritional problems are not peculiar to countries where food is scarce. Protein malnutrition is, in fact, a serious disease affecting nearly two-thirds of the world's population. There is, therefore, an urgent need for the exploitation of what is probably the major untapped source of food: products from seas and inland waters. . . . Your part in the task that lies ahead, like that of other dedicated people in commerce, in laboratories, in factories, farms and fishing boats, is to recreate the miracle of the loaves and fishes—a miracle no less spiritual for being scientific."

I am glad to have this opportunity of adding my own thanks, and those of FAO, to the many tributes already paid to all those who helped to ensure the smooth running and success of the Conference. Finally, in commending this book, I must express the hope that its study may soon result in a marked increase and improvement in the use of fish and fisheries products in the fight against hunger and malnutrition.

B. R. SEN
Director-General,
Food and Agriculture Organization
of the United Nations

INTRODUCTION

THE FAO Conference on Fish in Nutrition was unique in so far as it brought together for the first time on an international platform people working in fisheries, in production as well as research, with specialists in nutrition and animal feeding. Its object was to evaluate some of the existing knowledge of the rôle of fish in human and animal feeding, and to stimulate further study and exploration.

One such matter which emerged was the possible rôle of fish protein concentrates in human nutrition, a product which is not only needed now to relieve animal protein shortage in diets, but will become more and more necessary in nutrition as population density increases. It may be said that fish protein concentrates furnish a way of making directly available to man the richnesses of the multitudinous "small fishes" which abound in the ocean but are only slightly used in contrast to the larger and more expensive forms of fish which at present mark consumer taste.

The Nutrition Division and the Animal Production and Health Division of FAO, who are vitally concerned with developing a more extended use of food from the sea, collaborated extensively and, while it was left to the Fisheries Division to take the lead, the effort and the result must be regarded as the outcome of a joint undertaking.

The Conference was fortunate in having as its Chairman Mr. Donald McKernan, Director of the U.S. Bureau of Commercial Fisheries. This Bureau indeed was largely responsible for stimulating the interest and active support of the U.S. Government and of other national bodies. Thanks must also be expressed to the U.S. National Institutes of Health, whose grants made it possible to bring to Washington such an impressive number of distinguished experts.

Many people shared the work, not only of preparing the original papers, but also of getting these into suitable shape for presentation at the Conference. Amongst those who must be especially mentioned are A. G. van Veen, Nutrition Division of FAO; J. C. Shaw, Animal Production and Health Division; D. G. Snyder, Bureau of Commercial Fisheries, U.S.A., who acted as associated editors, assisted by A. D. Ingram-Schirato, and M. R. Khan, Fisheries Division, who prepared the index. Other tasks fell to members of our staff: M. Laing, P. McLaughlin, P. Andrews, D. D. Tapiador, M. C. de Freitas. The translations were done by P. M. Frances and A. M. Rosfelder.

Conferences such as this one serve to catalyse action. It is to be hoped that the rate of progress will be an increasing one and that steady advances on many fronts will be made to the end that man may harvest and put to better use a crop which is, after all, a gift of nature.

D. B. FINN
Director, Fisheries Division
Food and Agriculture Organization
of the United Nations

NOTE FROM THE CHAIRMAN

"THE seas offer a wealth of nutritional resources. They already are a principal source of protein. They can provide many times the current food supply if we but learn how to garner and husband this self-renewing larder. To meet the vast needs of an expanding population, the bounty of the sea must be made more available. Within two decades, our own nation will require over a million more tons of seafood than we now harvest."

This statement, made by President Kennedy in a message to Congress in March 1961, delineates in a few words the theme and objective of the FAO International Conference on Fish in Nutrition, held in Washington, D.C., on September 19–27, 1961.

This Conference was indeed convened to discuss how the living resources of the sea—first harvested by our fishermen and then processed by our fish plants—have contributed in the past and can contribute in the future to man's health and welfare.

In fact, FAO has recently postulated that these marine resources even now produce a larger supply than that from cattle and swine on the land. The stark realities of the world population explosion and of world hunger cannot be longer ignored. Viewed against this background of hungry multitudes, the discussions and presentations covered in this book assume historic importance. Few question the estimates of demographers that world population is increasing at a rate never before experienced in the history of man. It has been estimated that in A.D. 1600 the population of the earth was 300 to 400 million people. Two centuries later this figure had doubled and from then on population growth accelerated at an ever-increasing rate. By 1900, the population had risen to about 1,500 millions and during the last 60 years that figure doubled again. An indication of what is going to happen in the future is given by many experts, who forecast that within the next 40 years we will have reached the 6 billion mark.

On the other hand, nutritionists from the Food and Agriculture Organization, the World Health Organization, and other international agencies, in assessing the present state of food production in the world, estimate that two-thirds of the present world population does not receive an adequate daily diet.

One child dies of hunger every second of the year; of the 900 million children under 15 years of age, more than 500 million live and die critically undernourished and the catalogue of associated miseries could be continued over many pages, with statistics collected from all the continents.

Hunger can mean many things to various people. The term commonly describes conditions ranging from acute, extreme starvation to the symptoms of "hidden hunger". By and large, however, the dietary nutrient most lacking in deficient diets all over the world is good quality protein.

What is understood by this term "good quality protein"?

In man's long and arduous struggle to understand the nature, composition and function of foodstuff, he at least learned that Hippocrates was wrong when he said, some thousands of years ago, that man required nothing but energy to subsist. We know today that the human body requires a large number of different components which it cannot synthesize itself. Among these are certain protein components, called essential amino acids, and it is the combined presence and proportions of these in foods that determine their value. Only animal proteins contain all the essential amino acids that man cannot synthesize himself, and only animal proteins are, without supplementation, considered to be "good quality proteins".

Good quality proteins are not universally available in sufficient quantities in the form of agricultural products. Furthermore, land resources for crops and animal grazing are not inexhaustible; only one-fifth of the total available crop land is left unutilized and this, at best, could only supply enough food (predominantly vegetable) for presently underfed peoples—and this only if the most modern agricultural methods could be applied world-wide. Even if this could be achieved—and great capital expenditures and major educational and technological efforts will have to be made in this direction—there would still be a serious deficit in the supply of animal proteins to supplement adequately the diets of today's population, let alone that of tomorrow's additional millions.

In view of this, it is not surprising that, in their quest for food, scientists and industrialists all over the world have again focused their attention upon the seas as a vast potential source of nutrients.

The high nutritive value of fish protein has been recognized since earliest times, but notable utilization of this food has always been limited to certain areas owing, in part, to the extremely perishable nature of fish.

As the first topic to be considered at this Conference, it seemed logical to review the rôle of fish in world nutrition. It seems strange with over three-quarters of our globe covered by the sea, and with living matter found not only in the surface film but to some degree at least at all intermediate levels even down to the great depths within the ocean, that such a small amount of our present total food supply is contributed by the sea. Our present-day harvest of some 40 million metric tons of fish and fisheries products provides only a small part of the food consumed in the world today. This figure is significant in view of the fact that the current annual food deficit has been estimated to be greater than the present total world fish production.

We considered at this Conference to what extent the sea could contribute to this great need for food for the future. We examined the potential productivity of the sea and the practicability of doubling or even tripling the harvest of its living resources. We went even one step further and examined briefly what means or methods, what research and engineering, are going to be necessary to bring about the full use of the living resources of the world's oceans.

Our second topic at the Conference was to examine the chemical composition of fish and fisheries products in order to ascertain their wholesomeness and the desirability of using fish protein to an increasing extent in the human diet. We wanted to know to what extent is knowledge available which will allow us to assess the nutritional attributes of fish protein, and are there unique qualities in fish which can be helpful in overcoming the protein deficiencies in the human diet?

Experts present at this Conference discussed the present state of knowledge concerning how fish should be prepared to provide maximum nutritional benefits. We know there are nutrient losses in the preparation and processing of fisheries products. Can we develop specific information on how these losses occur and in what directions must we go to maximize, by special processing, the benefits from the fish resources harvested? How can we use existing information, and develop new information, to provide a maximum amount of the kinds of nutrients which are needed in various national diets?

The third general topic concerned the contribution of fish and fisheries products in the various national diets. It is obvious that we need to assess the present contribution, to determine what limitations exist, and what can be done to overcome these limitations to the greater use of fish in nutrition.

This Conference, as represented by the present book, has attempted, for the first time, to bring before the world the various means for increasing not only the harvest of fish but also the number, variety, and nutritive value of the products manufactured therefrom, and thus permit fish to assume, on a world-wide basis, its rightful rôle in human nutrition.

The realization of these objectives has taxed the energies of all participants, but I believe that the set goals have, to a large extent, been reached. This Conference and the concerted, international efforts that it represents can, of necessity, be only a modest beginning. Much remains to be done, for the overall task of providing additional food for our world's peoples is urgent and the obligations compelling. It is our hope that this book will inspire continued efforts to make the benefits of nutritious foods available to all of mankind.

Great credit is due the FAO for its foresight in having perceived the need for this Conference and for the organizational work associated with it as well as to the respective FAO-member nations for their enlightened support of its objectives. Congratulations are due also to the many people who have contributed so freely and wholeheartedly of their time and effort in order that this valuable reference text could be made quickly available to those in need of information on the nutritive value of fish and shellfish.

Donald L. McKernan.

Chairman,
FAO Conference on Fish in Nutrition

PART I

THE ROLE OF FISH IN WORLD NUTRITION

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THE WORLD BIOMASS OF MARINE FISHES

by

HERBERT W. GRAHAM and ROBERT L. EDWARDS

Many people believe that the 300 million cubic miles of salt water in the oceans have a comparably vast potential as a source of protein food. Under present conditions, however, there is a definite limit to this protein potential, at least in so far as marine fish are concerned.

The most productive fishing areas are various grounds on Continental Shelves, especially in the northern hemisphere and in areas of the oceans where phytoplankton production is relatively high. Many of these areas are probably approaching peak production now. A computation of potential world harvest, based on the catch of fish per unit area on representative productive Continental Shelf areas, yields an estimated annual harvest potential of 55 million metric tons.

Using the estimated net primary production in all oceans as another basis for computation, it is estimated that approximately 115 million metric tons of marine fish are potentially available for harvest annually. However, a large portion of this production is too thinly scattered to be economically fished at this time.

It is shown that a relation exists between fish catch and benthic biomass. Inasmuch as the benthic biomass decreases very rapidly with depth, one cannot expect any substantial population of fishes on the bottom beyond the Continental Shelves.

There appears to be no reason to suggest that, under present conditions and with present fishing techniques, the annual harvest of marine fishes can be more than doubled or, at the very most, tripled. It is estimated that a reasonable expectation might be about 60 million metric tons annually.

LA BIOMASSE MONDIALE DES POISSONS MARINS

Beaucoup de personnes croient que les 300 millions de milles cubiques d'eau salée des océans représentent un potentiel relativement vaste comme source d'aliments protéiques. Sous les conditions actuelles, cependant, il existe une limite définie à ce potentiel protéique, au moins en ce qui concerne les poissons marins.

Les zones de pêche les plus productives sont des fonds divers sur les plateaux continentaux, spécialement dans l'hémisphère nord et dans les régions océaniques où la production de phytoplancton est relativement haute. Un calcul de la récolte potentielle mondiale, basée sur la quantité pêchée par unité de surface sur les zones de production représentatives du plateau continental, permet d'estimer à 55 millions de tonnes métriques le potentiel annuel de récolte.

En prenant comme autre base d'appréciation la production primaire nette estimée de tous les océans, on arrive à chiffrer à 115 millions environ de tonnes la quantité de poisson disponible en puissance pour être récoltée chaque année. Cependant, une large part de cette production est trop clairsemée pour être pêchée d'une manière économique durant cette période.

Il est démontré qu'une relation existe entre la capture du poisson et la biomasse benthique. Etant donné que la biomasse benthique décroît très rapidement avec la profondeur, on ne peut s'attendre à trouver une population substantielle de poissons sur le fond au delà des plateaux continentaux.

Il semble ainsi qu'il n'y ait pas de raison de penser que, sous les conditions actuelles et avec les présentes techniques de pêche, la récolte annuelle de poissons marins puisse être plus que doublée, voire triplée. On peut estimer les possibilités raisonnables à 60 millions environ de tonnes métriques par an.

LA BIOMASA MUNDIAL DE LOS PECES MARINOS

Cree mucha gente que los 300 millones de millas cúbicas de agua salada en los océanos tienen un vasto potencial comparable como fuente de alimento proteico. Sin embargo, en las circumstancias actuales hay un límite claro a este potencial, por lo menos en cuanto se refiere a los peces marinos.

Las zonas pesqueras más productivas son varios bancos en las plataformas continentales, especialmente en el hemisferio norte, y en regiones oceánicas en las que la producción de fitoplancton es relativamente elevada. Muchas de estas regiones probablemente se aproximan a su producción máxima en estos momentos. El cómputo de la cosecha mundial potencial, basado en la pesca por unidad de volumen en puntos representativos productivos de la plataforma continental, da un potencial de pesca anual estimado en 55 millones de toneladas métricas.

Empleando la producción primaria neta estimada para todos los océanos como base del cómputo, se calcula que hay una disponibilidad potencial de 115 millones de toneladas métricas de peces para cosecharlos anualmente. Sin embargo, una gran proporción de esta cantidad no está lo suficientemente concentrada para pescarla económicamente en la actualidad.

Se sabe que existe una relación entre las capturas y la biomasa del bentos. Dado que la biomasa del bentos decrece muy rápidamente con la profundidad, no se puede esperar que existan poblaciones substanciales de peces en el fondo, más allá de las plataformas continentales.

No parece que existan razones para sugerir que en las condiciones y con las técnicas de pesca actuales la cosecha anual de peces marinos se pueda duplicar o, a lo sumo, triplicar. Se estima que una espectativa razonable podría ser alrededor de 60 millones de toneladas métricas anuales.

EVERY cubic mile of sea water contains 140 lb. of gold. At this thought you might well ask, what kind of a sieve do I need to strain out this valuable metal? Granted you had the perfect sieve, it would not be practical to remove the gold. A little calculation will show that to strain one cubic mile of sea water through any kind of device would require pumping 50,000 gallons of water every second continuously for one year, obviously an impractical procedure.

We are continuously bombarded by press, radio, and scientific articles with facts and figures designed to impress us with the vastness of the oceans. The oceans are indeed vast, comprising some 300 million cubic miles of sea water. However, as N. W. Rakestraw (8) points out, "It is, in reality, scarcely more than a film of moisture", when one considers the total amount of material in the world. It is, obviously, a matter of perspective.

The total marine fish biomass must also be a figure of such size as to stagger the imagination. However, we have the required sieves to harvest at least part of that resource. These sieves are in the shape of such tools as otter trawls, gill nets, and purse seines. We have one further, but very important, factor in our favour. Fishes are not randomly distributed, as are the atoms of gold. Most of them are, to some degree, concentrated by their hydrographic climate, by geography, and by social behaviour (1). A significant part of the total resource still may be so thinly scattered that it is like the gold, not harvestable on any practical basis. We will try to present a case here for suggesting, pending totally new and as yet unforeseen techniques of fishing and marine pisciculture, that there is a limit to the amount of fish that may be harvested each year; that this maximum quantity may be estimated within reasonable limits; and, finally, that it is not greatly in excess of what is presently being harvested.

What is being harvested at the present time? Since World War II, various fisheries have developed around the world that have never before been seriously exploited by man. Some of the more recently exploited populations include the tuna stocks of the South Atlantic, the anchovy of Peru and Chile, the sardine of South Africa, and the groundfishes of the Barents Sea. In the last 10 years landings from the oceans have nearly doubled. All of these new fisheries were known to exist as potential fisheries long before they were seriously fished by man. Few such remain, and continued growth at this rate and along these lines cannot be anticipated. According to the most recent FAO (1960) statistics (Table I), approximately 35 million metric tons of fish and other related products, both from fresh and salt water, were landed in 1959. Of this total, marine fin fishes accounted for about 28 million metric tons.

TABLE I

Present landings of marine fish in millions of metric tons. An estimate based, in part, on FAO statistics for 1959

Species groups	*Millions of metric tons*
Salmon	0·9
Flounders	1·2
Groundfish	6·2
Clupeoids	11·4
Tunas	2·7
Jacks and mullets	4·9
Sharks and rays	0·5
Total fish	27·8

The clupeoids contribute the largest share, in excess of 11 million metric tons. These fishes are usually taken with purse seines, or in traps and weirs. Included in this group are the herrings, sardines, menhaden, and anchovies. It should be noted that some of these species, in part or entirely, are not directly used for human food. The menhaden, for example, is taken in part for its oil, which finds its way into many products other than foodstuffs. Sardines and anchovies largely support the fish meal industry.

The next largest contribution is made by the groundfish species, and amounts to more than 6 million metric tons. These are the species that typically inhabit the great offshore fishing banks, such as the Grand Bank of Newfoundland, and are fished, for the most part, with otter trawls. The most famous of these fishes is, perhaps, the Atlantic cod.

The jacks, mullets, and sea basses, a most heterogeneous group from a taxonomic and fisheries viewpoint, are recognized as a single group for the purpose of landing statistics by the FAO. As such they contribute nearly 5 million metric tons to the annual landings.

Tuna landings amount to slightly less than 2·7 million metric tons a year, and flounder landings to slightly more than 1 million metric tons.

The important fisheries of the world are, without exception, associated either with the Continental Shelf or with areas of regular hydrographic disturbance, such as upwelling or mixing of great oceanic currents. Quite obviously the reason for this goes back to the relative success of the plants in these areas. These are the areas where, as Sverdrup (10) says, "the oceans plow themselves".

Over the entire globe there are approximately 6×10^9 acres of potentially productive Continental Shelf. Without making any special allowances for differential latitudinal effects, what might we expect eventually to harvest from this area?

In Tables II and III we have tabulated the results of some calculations made on the yearly harvest of demersal species (gadids, hakes, flounders, etc.) from the Conti-

TABLE II

Demersal and pelagic species landed from Continental Shelf of North-west Atlantic each year, in millions of lb. Data based on an average of statistics available for years 1956 through 1958

Location	*Demersal*	*Pelagic*	*Total*
Grand Bank	1,226	18	1,244
Nova Scotia	835	215	1,050
Gulf of Maine	584	216	800
Middle Atlantic	146	1,029	1,175

TABLE III

Catch in lb./acre/year from the Continental Shelf of the North-west Atlantic

Location	*Demersal*	*Pelagic*	*Total*
Grand Bank	11·8	0·2	12·0
Nova Scotia	10·8	2·8	13·6
Gulf of Maine	12·7	4·7	17·4
Middle Atlantic	7·7	54·2	61·9

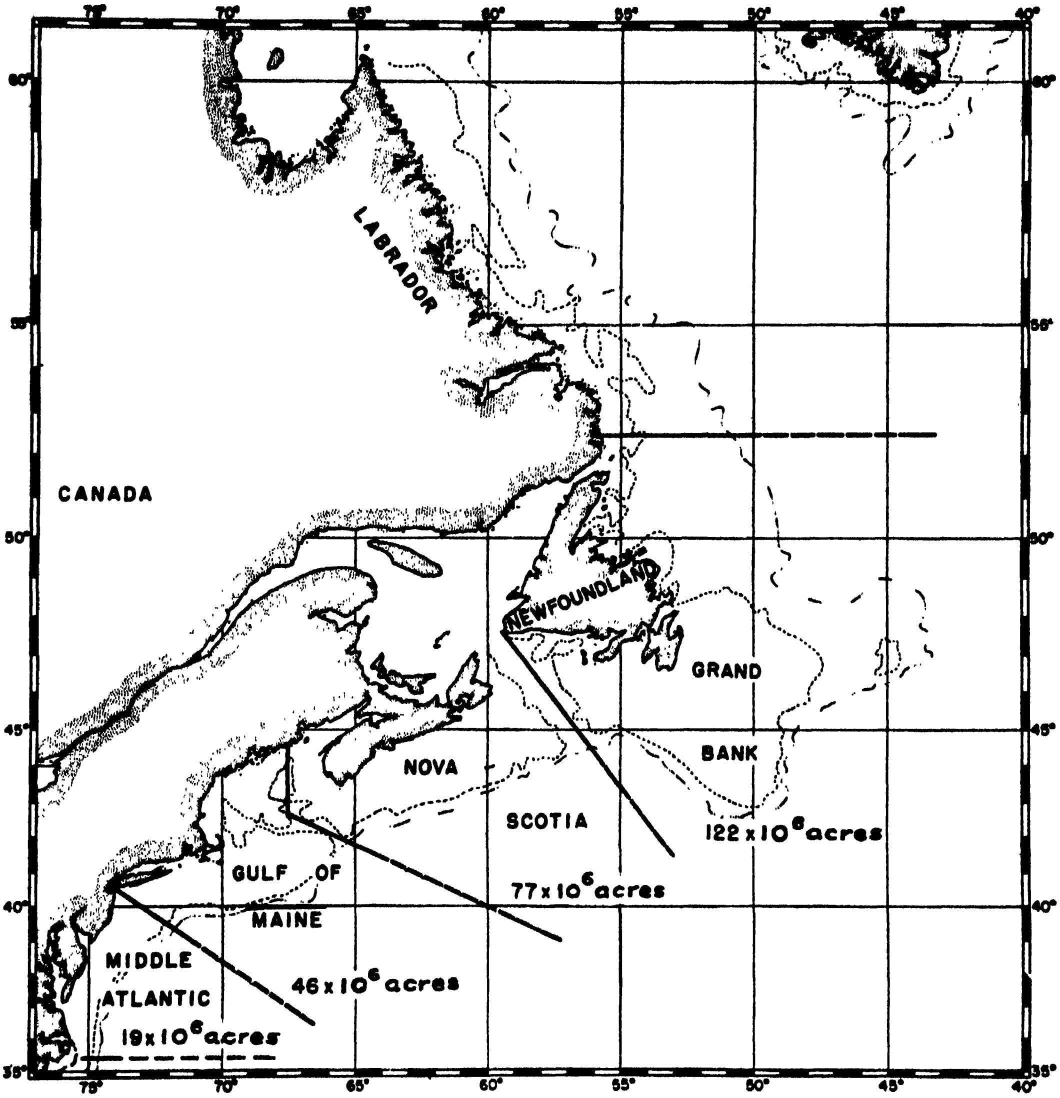

Fig. 1. The Continental Shelf of the North-west Atlantic showing four areas referred to in the text

nental Shelf of the North-west Atlantic. This area, shown in Fig. 1, has been divided into four sub-areas, to facilitate using the available fishery statistics.

The harvest levels of demersal species, from 7·7 to 12·7 lb. per acre, are surprisingly similar. The northernmost three areas are intensively fished by vessels from many countries. While it is not generally believed that they are necessarily overfished, neither is it apparent that production can be markedly increased. The demersal species of the Middle Atlantic are probably not yet fully exploited, and accordingly the harvest rate is low compared with that of the other three areas. The pelagic harvest rates, on the other hand, vary extremely, from 0·2 to 54·2 lb. per acre. There is an interesting increase in harvest of pelagic species southward in this region. This is due to the increased abundance of harvestable pelagic species, the menhaden accounting for the increase in the Gulf of Maine and Middle Atlantic.

TABLE IV

Catch in lb./acre of various well-known fishing areas. Computations by authors based on statistics from several sources

Location	*Period*	*Demersal*	*Pelagic*	*Total*
North Sea . .	1956–58	10·0	16·6	26·6
Baltic . . .	1956–58	4·1	3·5	7·8
Barents Sea . .	1956–58	15·7	0·8	16·5
Iceland Banks . .	1956–58	29·0	5·3	34·3
Adriatic† . .	1947–53	2·5	2·1	4·6

† The Adriatic is generally considered to be overfished.

Similar harvest figures were calculated for areas in European waters. These are presented in Table IV. Although there is more variation in the harvest of demersal species from area to area, the values are, on the whole, similar to those obtained for the Western Atlantic.

The fishing banks of the North Atlantic are among the more productive in the world, and have been exploited for centuries. Although the harvest has increased a little in recent years, we can say that in general the fisheries have stabilized, at least for certain species. Although management measures will prevent over-exploitation and may result in some increase in harvest, we cannot expect the harvest of these species from these banks to increase by any great percentage.

For purposes of computing the possible world harvest from all Continental Shelves, we can use the values for North Atlantic banks. Let us pick 20 lb. per acre as a conservative average figure. On this basis, the total Continental Shelf yield would be 120 billion lb. or 55 million metric tons per year.

To this might be added some poundage of pelagic fish taken in areas remote from land. This harvest is not expected to be large. Even though some tuna fisheries are prosecuted in the equatorial regions of disturbed hydrographic conditions, many of the tuna fisheries are associated with the Continental Shelf and the yields are properly assigned to the figures computed above.

Thus, we can say on the basis of these calculations that we may, at best, possibly double present world harvest of marine fishes. This is assuming, of course, that the fish on all parts of the Continental Shelf will be as available and as economical to harvest as those of the North Atlantic banks.

We can arrive at another estimate of potential world harvest of marine fishes by an independent, more theoretical technique. This technique, which has been used by Kesteven and Holt (4), is based upon our knowledge of the primary organic production in the sea and its relation to the production of fish usable by man. Many assumptions regarding the food chain in the sea are involved, but none of these do violence to the beliefs of modern ecologists (7). The first of these is that herbivores are 20 per cent efficient, and each following link in the (carnivore) food chain is approximately 10 per cent efficient. The second is that the average marine fish is a second level carnivore. The third is that the net production at each trophic level is fully available to each succeeding level.

For these calculations we begin with an estimate of the net primary production of all oceans. Stéemann Nielsen (6) has recently summarized the literature on this subject, and has estimated the average annual gross primary production to be between 55 and 70 gm. C/m^2, and the total net production about $1{\cdot}2$ to $1{\cdot}5 \times 10^{10}$ tons of carbon.

Multiplying by 37 [to convert from grams of carbon to wet plankton weight: conversion factor from Sverdrup *et al.* (11)], we may obtain the net amount of phytoplankton produced each year: $(1{\cdot}2\text{–}1{\cdot}5 \times 10^{10}) \times 37 = 44{\cdot}5\text{–}55{\cdot}5 \times 10^{10}$. We will use the average value of 50×10^{10}. Let us assume that the herbivores (zooplankton) fully harvest this net production and are 20 per cent efficient: then $(50 \times 10^{10}) \times 0{\cdot}20 = 10{\cdot}0 \times 10^{10}$ tons of herbivores (zooplankton). Primary carnivore production at an efficiency of 10 per cent is then $(10{\cdot}0 \times 10^{10}) \times 0{\cdot}10 = 10{\cdot}0 \times 10^9$ tons of primary carnivores, and $(10{\cdot}0 \times 10^9) \times 0{\cdot}10 = 10{\cdot}0 \times 10^8$ tons of secondary carnivores, marine animals of all descriptions, from which man may take his harvest.

One billion metric tons of secondary carnivores is a very big figure, but hardly indicative of what we can expect in the way of bony fishes, even under the best of circumstances. What then is a reasonable figure?

We have calculated on the basis of an ideal system. Some farm fish ponds have nearly reached the levels of efficiency used in the calculations. Odum (7, p. 79) states that "... it is evident that only in the intensively managed German and Oriental fish ponds is a harvest even approaching 10 per cent of gross primary production obtained." On the other hand, few if any natural situations have been found that even remotely approach these various levels of production, individually or collectively.

Evidence that energy is shunted away at various production levels is observed in the bottom deposits of the oceans. There are many types of "oozes", composed largely of the remains of different kinds of organisms. Typical of these are the "diatomacetous" oozes in the North Pacific and around the Antarctic Continent, the "pteropod" oozes of the Atlantic basins and the widespread "globigerina" oozes found in all oceans. Other evidence of sidetracked production may be seen in various fossil deposits, notably the petroleum deposits.

If we assume that in the marine situation 70 per cent of the theoretical energy transfer is actively attained at all levels, our estimated annual production of secondary carnivores is approximately 343 million metric tons. Included in this figure, in addition to the marine fishes in which we are principally interested, are many other marine animals such as squids, whales, and sharks, which we conservatively estimate make up one-third of the consuming biomass at this and higher consumer levels. All things considered, then, perhaps as much as 230 million metric tons of marine bony fishes are produced on an annual basis. Obviously, however, this quantity cannot be harvested annually without jeopardizing the resource's ability to renew itself. Properly harvested, it is reasonable to suggest that resources of this nature may yield 50 per cent by weight, at least, of the net annual production.

We estimate finally, therefore, that perhaps as much as 115 million metric tons of marine fishes may be available for harvest each year. A significant part of this resource is thinly scattered, like the gold; but our fishery technology will have to be greatly improved before a harvest of this magnitude is possible or feasible.

Clearly lacking from the marine environment as significant entities are the efficient herbivorous fishes, and for good reason. Marine plant populations are not characterized by their stability; they are subject to violent fluctuations in abundance, the well-known plankton blooms, the degree of which depends upon the nature and source of nutrients. These nutrients are seldom con-

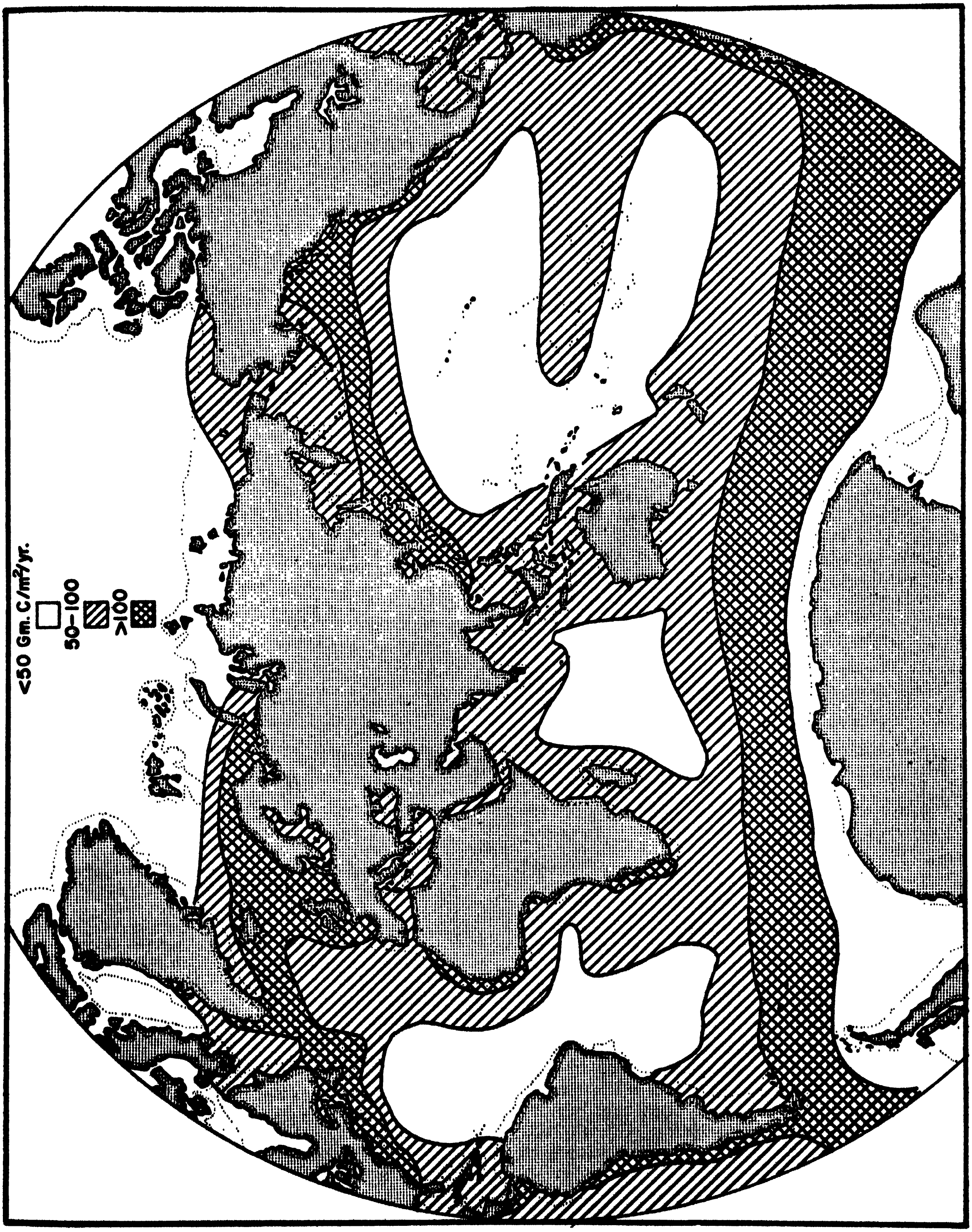

Fig. 2. Generalized chart of net primary production

tinuously present, and one or more of them (e.g. iron) (5) are frequently in such short supply that production rates over a fair proportion of the oceans do not exceed those of semi-arid grasslands.

The distribution of areas of comparable net primary productivity is shown in Fig. 2. It is worth noting that mid-ocean areas are generally unproductive, while the higher latitudes, both north and south, are exceedingly productive. The reasons for this have been amply and well explained by Sverdrup (10). We are concerned with this differential distribution of plant production because it qualifies our estimate, given earlier, for the practical expectation of harvest from the Continental Shelves. Except in certain well-known areas where upwelling occurs (as, for example, off the west coast of Africa, South, and North America) the Continental Shelf areas of the low and mid-latitudes are characterized by only moderate levels of primary production. On the other hand, most of those areas of shelf characterized by high levels of primary production are already heavily fished. Accordingly, we feel our first estimate of potential groundfish harvest on the Continental Shelf to be, if anything, too high.

With reference to the various harvest rates listed in Tables III and IV, we feel that the differences shown are probably quite real. Moiseev (in UNESCO, 1955) lists the biomass of the benthos in a number of seas. A comparison of these data is possible with three of the areas for which we have computed fish harvest rates (Table V). Some relationship is strongly implied and, of course, gives us greater confidence in our fish yield figures.

TABLE V

A comparison of fish yields with amount of benthos

Location	*Biomass of benthos (g/m^2)*	*lb./acre fish (1956–58)*
North Sea	244	26·6
Baltic Sea	33	7·8
Barents Sea	100	16·5

The relation between the benthic biomass and catch per acre has the broadest of implications. The benthic biomass decreases even faster, as one moves offshore, than does the plankton of the photic zone. According to Zenkevich (UN, 1956), in his discussion of the research done in the North-west Pacific area, the benthos decreases two to three thousand times in quantity from the littoral zone to the central parts of the ocean. In these circumstances, one cannot expect to find any substantial fish population on the bottom beyond the Continental Slope.

To summarize, it seems reasonable to suggest that, although man has not yet fully exploited the marine fish resources, they are not so vast as some have been led to believe. Pending the development of totally new fishing gear and feasible marine pisciculture techniques, such as control of species composition, management of harvest, and fertilization to raise the standing crops, considerably less than 60 million metric tons of marine fishes are at present available for harvest on an annual basis.

The authors wish to acknowledge the suggestions and criticisms of many people, especially Dr. Eugene Odum (University of Georgia), Sidney Holt (FAO, Rome), Howard Eckles (BCF, Washington, D.C.).

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WORLD AQUATIC BIOMASS—ITS FUTURE ABUNDANCE

by

G. L. KESTEVEN

This paper suggests the following points with regard to the general question, for which it is required to provide an answer:

(1) Any examination of what biomass there will be in the future must be qualitative;
(2) The question is an ecological one;
(3) There is a community biomass as well as a species biomass;
(4) An estimate of total biomass of the biosphere is of less interest than estimates of the biomass of each of many separate species and communities;
(5) There is less interest in the biomass of a standing crop than in the capacity of a community or species to produce biomass;
(6) The structure and magnitude, and hence biomass, of a community or of a species population, may vary within a season, seasonally and annually, and may exhibit a trend;
(7) Under natural conditions there may be a trend to increase biomass;
(8) Man's activities interfere with natural processes; in so far as he acts as predator on, or disturbs, natural systems, he may halt or reverse upward trends in them; however, he also has powers to act in a contrary sense.

The paper then examines man's role and seeks to show that:

(1) Even as predator, man can regulate his activities so as not to cause irremediable damage;
(2) The principle of eumetric fishing gives man a way of maximizing the productive capacity of a species population (stock of fish) under specified conditions;
(3) By an extension of the principle of eumetric fishing, man could probably increase community-productive-capacity; and if he could extend the range of species of which he could make use, he would have increased yield from the community;
(4) Man's activities as disturber (causer of erosion, producer of sewage and effluents, builder of dams, etc.) have both deleterious and beneficial effects; he has means to maximize the latter, and to minimize or even convert to his advantage the former;
(5) Man can intervene in natural systems to determine their structure and size and the pace of their processes, even in the sea; perhaps the most direct approach would be by a deepening of the application of eumetric fishing.

This review leads to the logical conclusion that the biomass of the future is likely to be as much more or less than it is now, as man makes it to be.

LA BIOMASSE AQUATIQUE MONDIALE: SON ABONDANCE FUTURE

Cet article propose les points suivants concernant le problème général:

(1) L'examen de ce que sera la biomasse dans le futur doit être qualitatif;
(2) Ce problème est un problème écologique;
(3) Il y a une biomasse de communautés comme une biomasse d'espèces;
(4) L'estimation de la biomasse totale de la biosphère est d'un intérêt inféreur à l'estimation de la biomasse de chacune de nombreuses espèces et communautés séparées;
(5) La biomasse d'une récolte constante est d'un intérêt infereur à celle de la capacité d'une communauté ou d'une espèce à produire une biomasse;
(6) La structure et l'importance, et, ainsi, la biomasse d'une communauté ou d'une population de même espèce, peuvent varier au cours d'une même saison, saisonnièrement et annuellement, et peuvent présenter une tendance générale dans leur évolution;
(7) Sous les conditions naturelles, il peut exister une tendance de la biomasse à l'augmentation;
(8) Les activités de l'homme interfèrent avec les processus naturels; dans la mesure où il agit comme prédateur ou comme perturbateur des systèmes naturels, il peut arrêter ou renverser complètement leurs tendances; cependant, il a également les pouvoirs d'agir en sens contraire.

Cet article examine le rôle de l'homme et cherche à montrer que:

(1) Même comme prédateur, l'homme peut régler ses activités de façon à ne pas faire de dommages irréparables;
(2) Le principe de la pêche rationnelle sélective ("eumetric fishing") donne à l'homme le moyen de rendre maximum la capacité de production d'une population de même espèce (stock de poisson) sous des conditions précises;
(3) En étendant le principe de la pêche rationnelle sélective, l'homme pourrait probablement accroître la capacité de production des communautés; et s'il pouvait accroître les variétés des espèces qu'il utilise, il pourrait augmenter la production de la communauté;
(4) Les activités de l'homme comme perturbateur (provoquant des érosions, produisant des eaux d'égouts et des effluents, construisant des barrages, etc.) ont à la fois des effets nocifs et des effets bénéfiques; il a les moyens d'accroître les seconds et de réduire les premiers, voire de les transformer à son avantage;
(5) L'homme peut intervenir dans les systèmes naturels pour déterminer leur structure ainsi que la grandeur et l'allure de leurs évolutions, même en mer; il est possible que l'approche la plus directe de ce problème soit dans l'approfondissement des applications de la pêche rationnelle sélective.

Cet examen conduit à dire que la seule conclusion logique est que la biomasse future sera vraisemblablement ce que l'homme la fera devenir, plus grande ou moindre qu'elle ne l'est aujourd'hui.

LA BIOMASA ACUATICA MUNDIAL: SU ABUNDANCIA FUTURA

Esta communicación propone los puntos siguientes concernientes al problema general:

(1) Cualquier examen de la biomasa que exista en el futuro tendrá que ser cualitativo;
(2) El problema es ecológico;
(3) Existe una biomasa de comunidades y una biomasa de especies;

(4) La estimación de la biomasa total de la biosfera tiene menos interés que la de la biomasa de cada una de las muchas especies y comunidades separadas;
(5) Interesa menos la biomasa de una cosecha constante que la capacidad de una comunidad o una especie de producir una biomasa;
(6) La estructura e importancia y, de aquí, la biomasa de una comunidad o de una poblacíon de una especie, puede variar dentro de la estación, estacional y anualmente, y puede presentar una tendencia general de su evolución;
(7) En condiciones naturales, puede existir una tendencia de la biomasa al aumento;
(8) Las actividades del hombre interfieren con los procesos naturales; en la medida en que actúa como predador o como perturbador de los sistemas naturales, puede detener o alterar sus tendencias ascendentes; sin embargo, también es capaz de actuar en sentido contrario.

El artículo pasa a examinar el papel del hombre y trata de demostrar que:

(1) Incluso como predador puede regular sus actividades para no causar daños irreparables;
(2) El principio de la pesca eumétrica ofrece al hombre un medio de hacer máxima la capacidad de producción de una población de la misma especie en condiciones precisas;
(3) Por extensión del principio de la pesca eumétrica, es probable que el hombre pudiera incrementar la capacidad productiva de las comunidades; y si pudiera acrecentar las variedades de peces de las que podría hacer uso, aumentaría el rendimiento de la comunidad;
(4) Las actividades del hombre como perturbador (causante de erosiones, productor de aguas de alcantarilla y efluentes, constructor de presas, etc.), tienen a la vez efectos nocivos y benéficos; dispone de los medios de acrecentar los últimos y de reducir al mínimo o, incluso, aprovechar los primeros.
(5) El hombre puede intervenir en los sistemas naturales para determinar su estructura y magnitud, así como sus evoluciones incluso en el mar; probablemente el enfoque más director consistiría en ampliar las aplicaciones de la pesca eumétrica.

De este estudio se deduce que la única conclusión lógica es que la biomasa del futuro será probablemente mucho mayor o mucho menor de lo que es actualmente, según como la haga el hombre.

IN discussions of the future of food supplies, where the contribution to be got from the world's waters is in question, it is common to begin with speculations about activities that may be labelled "farming the seas". Unfortunately, such discussions, besides bypassing a number of serious problems concerning most effective use of available resources in their present condition, tend to concentrate on the technological problems of giving effect to highly imaginative proposals formulated by analogy with agricultural or other operations. The magnitude of the biomass of aquatic resources of the future will be determined by processes preserving it at its present level or causing it to change from that level. To seek some conclusions on this matter, we must have some idea of what natural and man-initiated processes might cause such change. Talk of increasing the biomass by "fish-farming" suggests that man's intervention in these natural systems could outweigh other causes. Effective action to intervene in natural systems might be lit upon by accident, but can be rationally determined only from a deep understanding of the system to be changed. The principal theme of this paper then must be: to forecast the biomass of tomorrow, we must know the biosphere of today.

At this time an enquiry into what is likely to be the magnitude of the world's aquatic biomass in the future must be, of necessity, essentially qualitative in nature.

To predict the value which a characteristic of a productive system will have at some time in the future, one must be in possession of certain minimal information relating to the structure and dynamics of the system. In particular, one must have information on the "behaviour" of the selected characteristic. Despite the great advances of aquatic biology in recent years, we have to admit that there is scarcely a single integral system (community or ecosystem) of which we know so much that we could claim with confidence to be able to predict its behaviour for anything more than a very limited space of time. Recognizing also that we as yet have no inventory of the aquatic biosphere (all living organisms of the world's waters) in terms either of species-populations, or of communities or ecosystems, we must accept that we cannot predict the shape or magnitude that the biosphere will have some years hence. This is not to suggest that an estimate cannot as yet be made of the biomass existing at present; it simply asserts that we cannot forecast quantitatively the changes likely to take place in the biosphere. This view is expressed primarily with a thought to changes taking place naturally in the biosphere. How much more difficult is the problem if we wish to consider also the changes brought about by human activities! To indicate that human action is causing certain changes, or that human action could bring about certain other changes, is one thing; but to say whether the first action will continue, or whether the other action will be taken (or when it might be taken) is an entirely different matter.

The most, then, that we can hope to do is to try to form an idea whether the biosphere is showing any indication of a trend to change under compulsion of natural or human forces, and of whether such trend (if, in fact, it exists) is toward increase or decrease. We may also try to form an idea of whether there might be courses of action by which man could reverse a trend to decrease, or, on the other hand, could accelerate, or otherwise improve, a trend to increase. To make an essay of this kind, it is necessary to recapitulate some basic principles of the dynamics of biological systems and, in particular, of aquatic biological systems. This is because the whole question is a matter for ecological enquiry. Indeed, the question would best be approached by careful study of some ecological work such as the impressive monographic text *Principles of Animal Ecology*, by Allee, Emerson, Park, Park and Schmidt (1).

SOME BASIC ECOLOGICAL CONCEPTS

The term "biomass" is taken to mean "a quantity of living material"; one can consider the biomass of the population of a species as a "species biomass", or the biomass of the several species of a community as a "community biomass". It is relatively unimportant here that the amount of this material may be expressed as a weight or a volume, or that the material may be measured as dried weight or carbon equivalent or in other terms. In contrast a distinction must be seen between "biomass" and "resource", since the latter comprehends both the living organisms whose biomass may be measured, and the stores of materials and energy on which these organisms draw for their living processes and to which they return in due course. The importance of this distinction lies, for this discussion, in the fact that we must keep in mind that a primary determinant of the magnitude of any biological system is the quantity of nutrient materials available to its plant-life. However, the term "resource" is essentially an economic one, of which the meaning in plain words is "natural materials on which man can draw". For the purposes of this discussion, and to emphasize the ecological basis to the problems of examining changes in biomass, it is necessary to employ the counterpart ecological term, namely, "ecosystem". "Ecosystem" may be defined as "a community of organisms with their habitat, thus comprising living and non-living components that interact to varying degrees". Spatially, an ecosystem is approximately congruent with the community that constitutes its biological part. The essence of the term lies in its emphasis on the integration of living and non-living components and on the fact that such an integrated complex constitutes a system in which various processes take place; the connotation of this term is of deeper significance than that of the term "community" which, of its nature, is directed to the biological elements alone, regarding non-biological elements as outside the community *per se*. Discussion of ecosystems is more meaningful in the present context, in so far as we shall need to consider the changes that might be induced in natural systems; and very often a marked effect in the community can be produced most easily by action directed against the non-biological elements. It may be well to note here that basically the present discussion considers total biomass without regard to the economic use that might be made of it; the question of selective exploitation or cultivation of preferred species of organisms is treated as a consequential aspect of the problem.

The patterns of communities

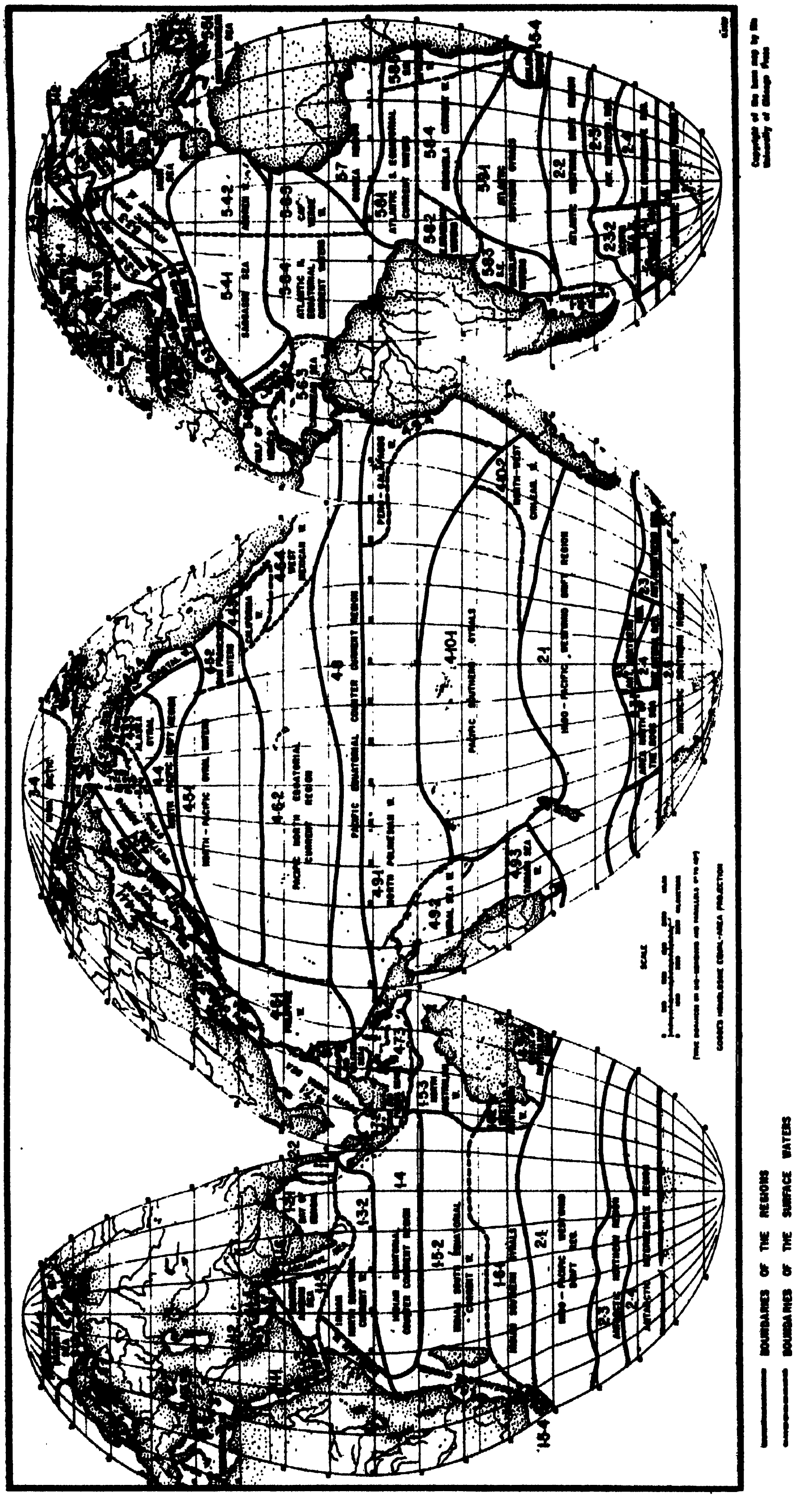
The living organisms of the world are referred to as its biosphere; obviously the biosphere cannot be a homogeneous mass of living matter—it is instead a complex pattern of communities, each of which is a complex assemblage of populations of species. It is important to bear in mind, for the purposes of this discussion (if not for other reasons), that the biosphere cannot usefully be treated as an unorganized assemblage of populations of species intermingling haphazardly; on the contrary, the species-populations are distributed systematically according to constraints imposed upon the existence of each species; the characteristics of the species and the nature of the factors of the environment are such that the effect of the constraints is to produce the pattern of communities. Although some authorities would regard marine biota as a single community, there is in fact a complex pattern of communities, especially of the benthos, but also of the pelagial. The latter is represented by the appended diagram of marine biogeographic areas (Fig. 1). A similar map for the continents would represent the diversity of freshwater biota.

The changes of communities

But these patterns (of communities within the biosphere and of species within communities) are not fixed; on the contrary, they are constantly changing. The population of each biological component of an ecosystem changes its structure and its magnitude seasonally, annually, and over extended periods; at the same time each supply-component (nutrient materials, oxygen, carbon dioxide, light energy) is subject to similar changes, and the intensity of each determinant factor (e.g. temperature and pH), which influences the life processes of the organisms and the use they make of materials, changes in similar ways. Of the changes of these sets, those of the determinant factors may be treated as independent of the changes of the other two. Changes in supply components are to varying degrees dependent on those of the biological populations; changes of biological populations are very largely dependent on those of supply components and of determinant factors.

Since biological populations interact, the pattern of them within a community is in constant flux, with changes that may be relatively small or relatively great; a task for this discussion is to examine the amplitude, period and direction of such changes. Similarly, the pattern of communities constituting the biosphere is in constant flux.

In order to understand the nature of major changes of biomass which take place in communities and in the biosphere as a whole, we must have a fairly clear understanding of the minor changes taking place in organisms and in populations of species, of which the major changes are the sum total. Thus, the cycle that each organism goes through, from single cell through embryonic and juvenile stages to maturity and senility and to its final dissolution after death, establishes a basic rhythm dominating all population processes. In the course of this cycle, but especially after reaching maturity, most organisms go through changes within each year (or reproductive period) as they pass through reproductive stages and possibly through distinct nutritional phases. In a steady-state condition a species-population achieves a characteristic structure with regard to the proportions


BOUNDARIES OF THE REGIONS
BOUNDARIES OF THE SURFACE WATERS
SCALE
GOODE'S HOMOLOSINE EQUAL-AREA PROJECTION
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PACIFIC EQUATORIAL COUNTER CURRENT REGION
SARGASSO SEA
ANTARCTIC CONVERGENCE REGION
INDO-PACIFIC WEST WIND DRIFT REGION

Fig. 1. Natural regions of the oceans (after Laevastu)

of its sexes, the proportions of immature and mature organisms, and the proportions of the several age groups. In each year, the biomass of such a population may fluctuate from one season to another as a consequence of reproduction, or of normal changes in food supply and feeding, and of similar processes (Fig. 2). Some populations are relatively unstable in consequence of precarious relations with other biological components, or of the uncertainty of supply components or determinant factors; in such cases there may be repression, or expansion, of the whole population, or in some cases these effects may appear selectively in particular groups, for in aquatic systems the fluctuations are often in the strength of the brood of young, so that dominant year-classes march through the age tables, as in the classical example furnished by Hjort with regard to herring (Fig. 3). Even in these less stable conditions, a population has an average level which is maintained over a relatively long series of years; that is to say, the average abundance of such a population can be ascertained therein only after many years of study, whereas in steadier populations the average can be ascertained after relatively few years.

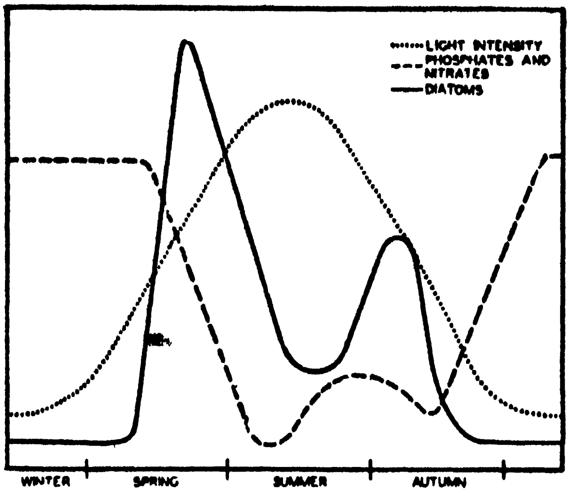

Fig. 2. Interrelation of the seasonal cycle in abundance of diatoms, light intensity, phosphates, and nitrates in the open North Atlantic. (From Park, Allee, and Shelford, after Russell and Yonge.) Allee et al. (1949)

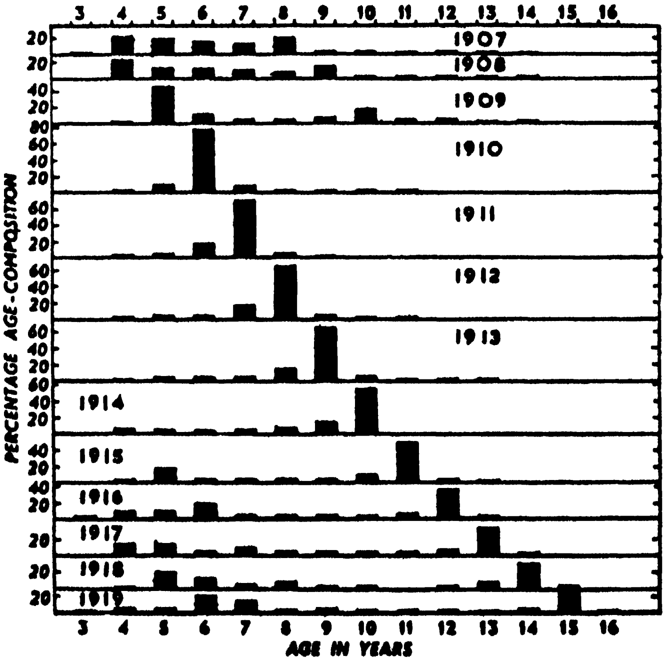

Fig. 3. A Predominant Year-class. Percentage age composition of Norwegian herring in successive years of observation. (After Hjort, 1926.) Michael Graham (1956)

In these situations the role of parasitism and of predation is of considerable importance. Even here, however, we again find that, despite the amplitude of the fluctuations that may be enforced by the interaction of prey and predator, and of host and parasite, neither population of each pair can be driven to extinction by the action or change of the other. Thus we see that basically the processes of natural populations, whilst producing changes in the abundance of each species, and in its biomass, maintain these populations at characteristic average levels.

However, major changes also take place that shift the average level of populations permanently, in some cases reducing the level to extinction, in other cases raising the population-abundance to a substantially higher level. Some of these changes are those known as seral succession, where one community is replaced by another, which in turn is replaced, and so on, until what is known as a climax-community becomes established. Such seral successions are familiar features of inland waters, estuaries and deltaic areas. In the open ocean the successional phenomena of coral reef islands afford a remarkable example of such sequences. Similar long-term changes presumably occur in pelagic, mid-water and benthic communities; but presumably they are associated with major climatic changes, such as those accompanying changes in the ice-cap. However, as discussed later,

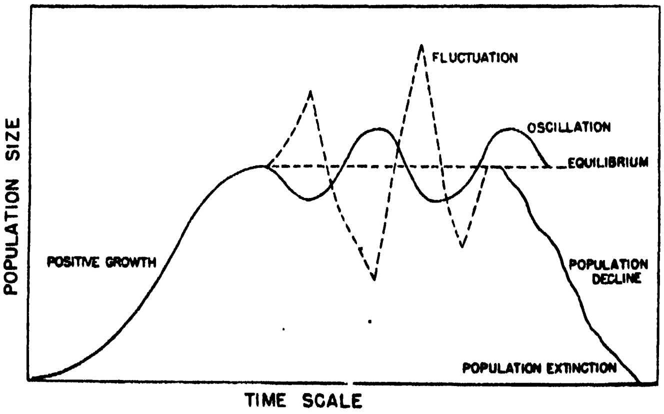

Fig. 4. Stylized representation of the various phases of population growth form. Allee et al. (1949)

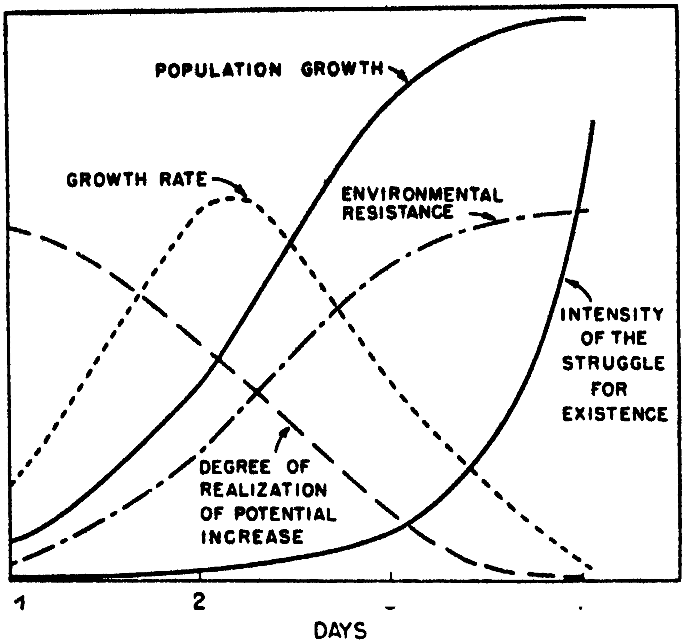

Fig. 5. Schematic representation of Gause's "characteristics of competition" exhibited by a population of paramecia growing logistically. In the text Gause's "degree of realization of the potential increase" is referred to as "unutilized opportunity for growth", and his "environmental resistance" as "utilized opportunity for growth". (From Gause.) Allee et al. (1949)

certain trends of this kind are produced by the activities of man.

Thus we see that populations, and communities, undergo changes that are of two kinds, those of oscillation and fluctuation about an average level and those of trend toward a new level. Both kinds of change must be considered in this examination of the prospects as to future biomass; for while the importance of trends is obvious, the oscillations and fluctuations, although less obvious, are possibly of greater importance in that they are more numerous and more deeply significant of the fundamental characteristics of the populations exhibiting them. This will be better seen after examination of Fig. 4 from Allee, Emerson, Park, Park and Schmidt (1), which represents the growth of a population up to the level where, although oscillating and fluctuating about an equilibrium value, the species exploits the possibilities of the habitat to the maximum of which its characteristics are capable. The sigmoid left-hand part of the curve is a typical growth curve, whose principal determinants are represented by Fig. 5 from Gause. Under relatively stable conditions, the population continues indefinitely at its equilibrium level, but a major unfavourable change will cause it to decline as represented by the right-hand side of Fig. 4. Under some circumstances (e.g. human exploitation) the population slides back down the left-hand slope to a lower level, at which it stabilizes itself (as represented in Fig. 6, from Ricker) (7). In contrast with such falls to lower levels, we must note that expan-

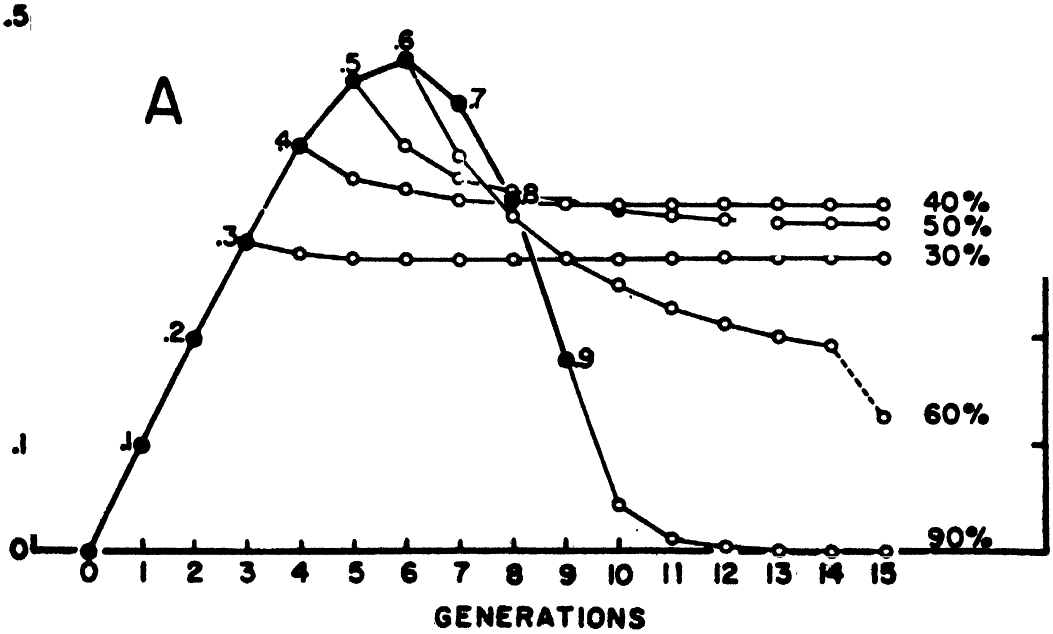

Fig. 6. Catches obtained from a stock whose reproduction is described by Curve A, conforming to the relationship $Z = We^{a(1-w)}$, *with a equal to 1·0. Solid dots: catches obtained when the rate of exploitation has successive absolute increases of 10 per cent per generation, starting with a stock at the replacement level. Open circles: catches obtained when the rate of exploitation remains constant at the levels shown, starting from the position described by the solid dot to which it is joined. The maximum sustained yield is obtained at 43 per cent, and is very slightly higher than the equilibrium level shown for 40 per cent. Ricker (1958)*

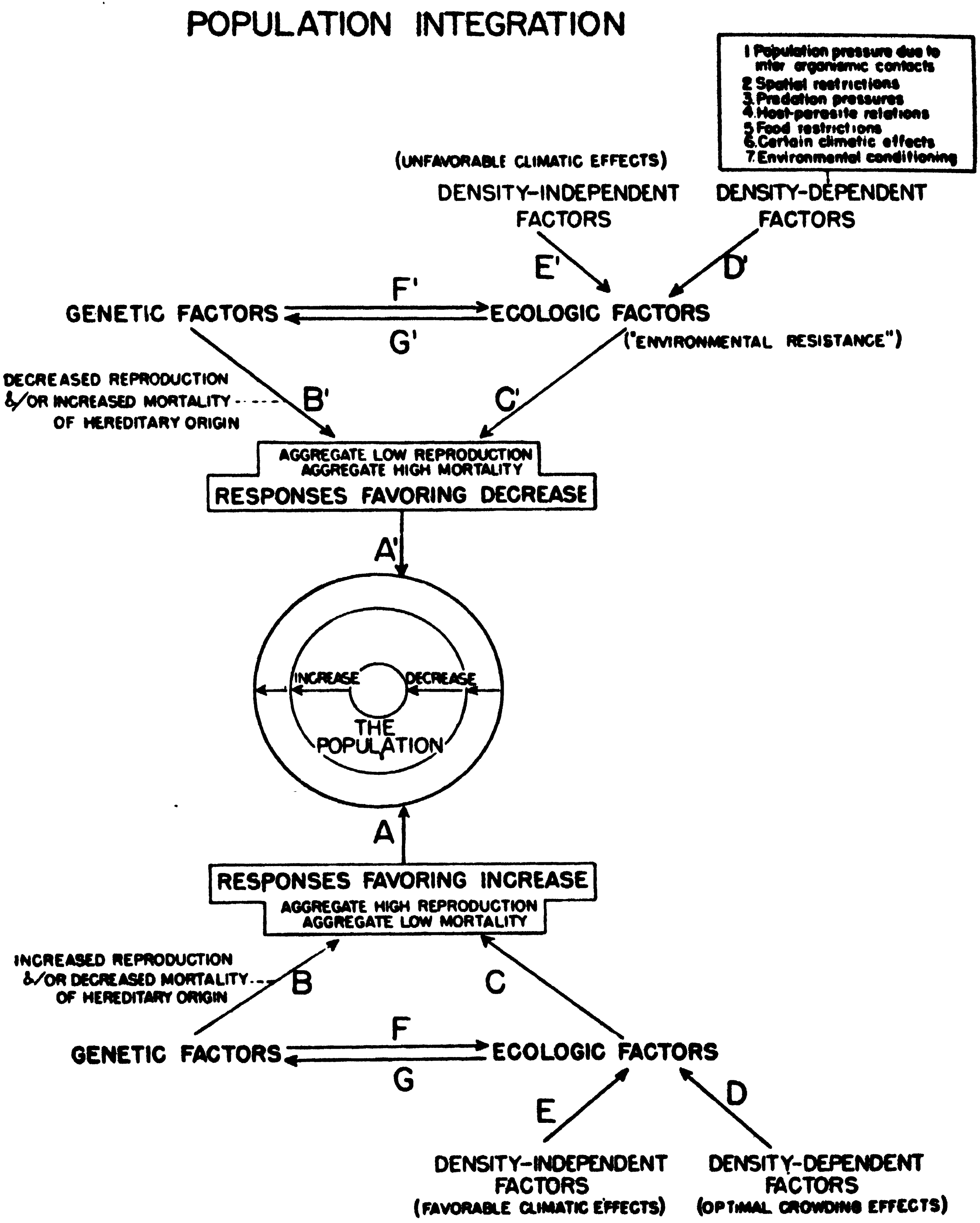
POPULATION INTEGRATION
1 Population pressure due to inter organismic contacts
2 Spatial restrictions
3. Predation pressures
4. Host-parasite relations
5 Food restrictions
6. Certain climatic effects
7. Environmental conditioning
(UNFAVORABLE CLIMATIC EFFECTS)
DENSITY-INDEPENDENT FACTORS
DENSITY-DEPENDENT FACTORS
E'
D'
F'
GENETIC FACTORS
ECOLOGIC FACTORS
G'
("ENVIRONMENTAL RESISTANCE")
DECREASED REPRODUCTION &/OR INCREASED MORTALITY OF HEREDITARY ORIGIN
B'
C'
AGGREGATE LOW REPRODUCTION
AGGREGATE HIGH MORTALITY
RESPONSES FAVORING DECREASE
A'
INCREASE
DECREASE
THE POPULATION
A
RESPONSES FAVORING INCREASE
AGGREGATE HIGH REPRODUCTION
AGGREGATE LOW MORTALITY
INCREASED REPRODUCTION &/OR DECREASED MORTALITY OF HEREDITARY ORIGIN
B
C
F
GENETIC FACTORS
ECOLOGIC FACTORS
G
E
D
DENSITY-INDEPENDENT FACTORS (FAVORABLE CLIMATIC EFFECTS)
DENSITY-DEPENDENT FACTORS (OPTIMAL CROWDING EFFECTS)

Fig. 7. A schematic representation of the interplay of factors that affect populations. Allee et al. (1949)

sion of the habitat, or relaxation of some repressive factor, may permit the population to move from one equilibrium up to another. These phenomena of increase, stabilization and decrease result from the interplay of many factors (as represented in Fig. 7).

Production and productivity

We have now to examine some ideas on the relative productive efficiency of populations and communities in the different states referred to in the previous paragraphs. Here we must return to the concept of ecosystems. Since all organic production is the result of the operation of two key industries—bacterial reorganization of inorganic and organic compounds, and photosynthetic activity of plants—a primary determinant of the magnitude of a system is the nature and magnitude of the supply of nutrients. This, however, is only one of the determinants: the influence of physical factors on the use of raw materials made by the key operatives (bacteria and plants), and indeed the efficiency of the operatives in using their raw materials under the conditions in which they exist, are of similar rank. On this point, Allee *et al.* have made some observations. They make the following generalization with regard to the primary producers—"a large part of the planet's surface is covered with a relatively thin, taxonomically complex, structurally discontinuous layer of photosynthesizing protoplasm engaged in the common ecological response of organisms and communities to the physical environment, in the synthesis of carbohydrates". They point out that this generalization, with the few exceptions to it, raises the question of the efficiency of this photosynthesis. They go on to discuss some evidence showing that for typical north temperate communities the photosynthetic production of a deciduous forest (in terms of pounds of glucose per day, and growing season, per acre) was 25 per cent greater than that of a tall grass prairie, and 124 per cent greater than that of a lake. They then remark: "This extends the argument previously advanced that the higher development of stratification in forests is probably partially the cause of this higher productivity. This argument suggests that stratification of structure and photosynthetic productivity are expressions of the developing complexity of the community, making more space available, and increasing the amounts of carbohydrates and proteins." This increase in the utilization of the space lattice is accompanied by increasing utilization of time from the point of view of overlapping periodicities.

This then raises the question of whether under natural conditions there would not be, in the plant segment of the biosphere, a general trend toward fullest use of available space and most efficient use of available energy and materials. If a climax-plant-community exceeds in productivity all its preceding seral stages, is there (except for man's intervention) a progression toward maximum productivity?

When we turn to the succeeding links of food chains, to the herbivores and carnivores, we are confronted, for the purposes of this discussion, with a parallel set of questions. It would perhaps be meaningless to speculate whether the biomass of a completely plant biosphere would be greater than that of one including animals; such a speculation would imply a thought to persuade all humans to adopt vegetarianism, and to attempt to eliminate all animals that competed for vegetables which man could eat. Obviously, despite the wastages that occur in the course of transformation of plant protoplasm into animal protoplasm, our speculations cannot imply their elimination. In any case, the variety of materials offered by the natural biosphere is attractive to man; and this implies that what we are interested in is not a total biomass as such, but the total biomass of each of many different species. Nevertheless, there is much room for research into the efficiency of different meshes of food webs, and into the possibility of replacing inefficient meshes. In addition, we may consider the differences of efficiency of like communities in dissimilar situations, and again whether replacements might not be made. Finally, we may consider whether all natural communities are fully developed and organized. For instance, unoccupied niches are known to occur in nature.

To summarize, the biosphere, in addition to manifesting periodic oscillations, and aperiodic fluctuations, need not be regarded as being perfectly, fully, and finally organized; there is evidence that a trend to fuller occupation of available space and more efficient use of available energy and material is characteristic of some biological systems. At the same time, reduction is taking place in other systems; for example, the aquatic system of a lake which is becoming filled is steadily diminishing, and although the substitute (i.e. terrestrial) system might be more productive, the aquatic type of production is obviously reduced. Without a full inventory one cannot say whether the total world sum of biomass ecosystems, of which some are expanding, some are in a state of equilibrium, and some are contracting, is increasing, remaining steady, or diminishing. We must then consider whether man, whose activities can initiate a move away from a steady state, or the reversal or acceleration of an expanding or contracting state, might bring about significant increase in the total biomass. Finally we must try to form some idea of whether, supposing that man can exercise a significant influence, he will in practice be able to make significantly greater quantities of useful materials available for exploitation.

THE NATURE OF HUMAN INTERVENTION IN NATURAL AQUATIC SYSTEMS

Man's rôle in these systems is threefold:

(1) as predator;
(2) as disturber;
(3) as modifier.

These terms are used to give a simple indication of the nature of the human action; the discussion that has gone before has been necessary for a proper appreciation of these rôles and for the attempt to assess how human activity may influence biomass in the future.

As predator, man's rôle is essentially similar to that of natural predators. As disturber, his agricultural, engineering, industrial and other activities destroy habitats, disrupt communities, and in these and other ways modify the structure and dynamics of ecosystems. As modifier, man deliberately changes the structure and/or size of ecosystems, or even (as with ponds) creates ecosystems, so that they should produce materials of kinds he wants.

Man as predator: Removal activities

When fishing begins on a particular stock of fish, the immediate result must be a reduction of the population, in numbers and biomass. The reduction is not equal to the catch, since part of what is caught would have died from natural causes. The reduction of community biomass may be even less than catch-minus-some-proportion-of-it that would have gone to natural mortality, since removal of the catch means presumably greater survival of the organisms on which the caught fish had fed, except that the surviving members of the exploited population may each eat slightly more and take up the spare food left by those that have been caught. But then, by eating more, the surviving fish could grow more, and further offset the removal by the catch. Again, if the fishing removes older fish, the growing potential and efficiency of food utilization of the population can increase. However, continuation of fishing, especially if effort should be intensified and the catch increased, would then outpace the benefit from these effects, so that the biomass of the population would become substantially reduced. What then becomes of the food-species on which the exploited populations feed? Obviously they do not expand their populations indefinitely. Other components that also feed on these species expand to hold the food-species in check; nutritional and other limits of the habitat co-operate in restraining the food species. Removal of predators can lead to a prey species damaging its own situation, as demonstrated by the instance of deer populations on the Kaibal plateau, Arizona (cited by Allee *et al.*; see Fig. 8). The literature also contains reports of instances of accelerated growth-rate in a residual population, and of successional phenomena (a species population expanding to replace one that has been reduced), after growth of a fishery. Thus natural communities possess control mechanisms that,

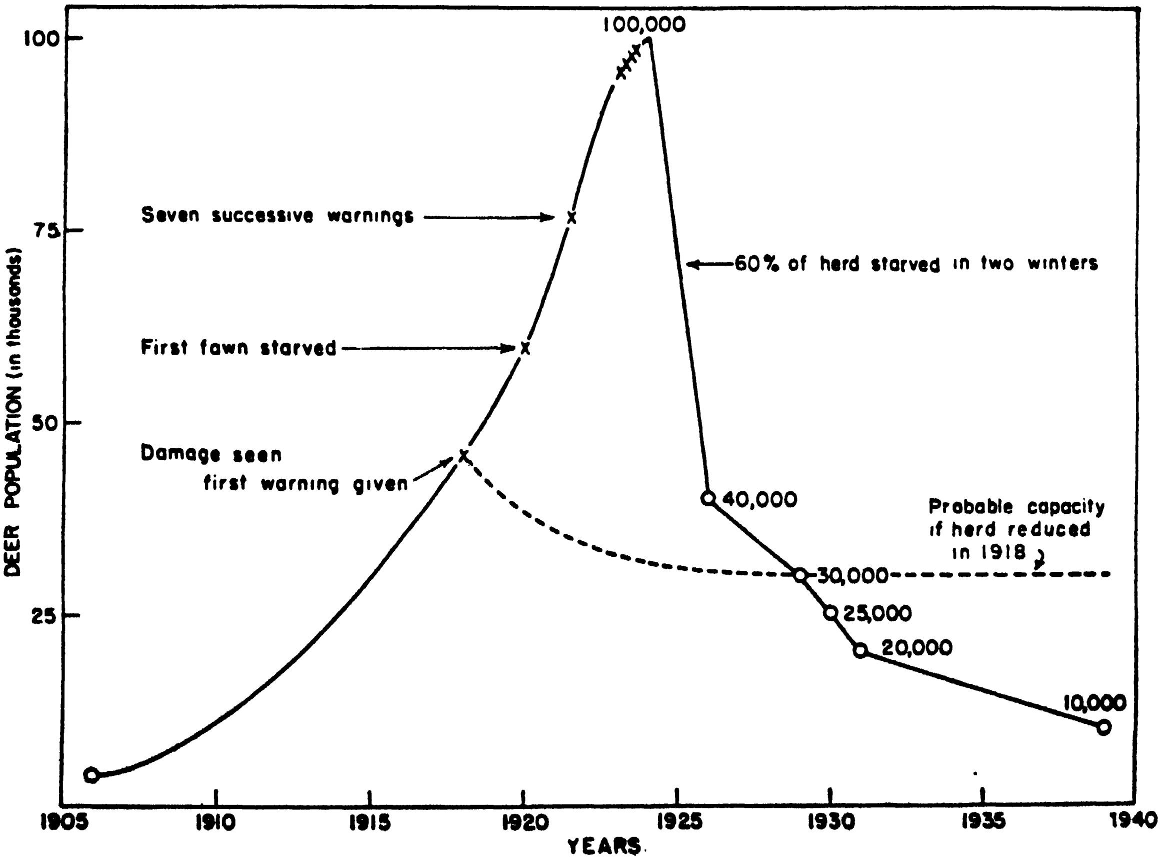

Fig. 8. The effect of removal of predators on populations of deer on the Kaibab plateau in Arizona (727,000 acres). Six hundred pumas were removed in 1907–17, 74 in 1918–23, and 142 in 1924–39. Eleven wolves were removed in 1907–23 and were exterminated by 1926. Three thousand coyotes were removed in 1907–23 and 4,388 in 1923–39. (Redrawn from Leopold.) Allee et al. (1949)

within certain limits of supply components and determinant factors, can buffer certain effects.

The theory of fishing, as developed by Beverton and Holt and others, has shown that the fishing of a species population can be regulated in such a way as to draw from the population a sustained yield at any of a number of different levels. Regulation of the characteristics of the fishing operations (intensity of effort, and selectivity, being the most important) in conformity with characteristics of the population, notably its growth and reproductive characteristics, can establish an equilibrium between growth, recruitment, natural mortality and fishing mortality, that will bring the population to maximum expression of its productive potential within the context of natural and human factors. Essentially, this means control of the total mortality to which the population is subject; whereas, as shown earlier, systems of this kind comprise many more factors, so that interference with one of them may produce repercussions through a lengthy chain of relations. The application of the principle of eumetric fishing could presumably be extended through the ecosystem so as also to influence, in appropriate sense and intensity, components and factors other than a fished population. Further examination of this idea might well be deferred to the section on man as modifier; but at this point we must examine further the question of whether man's predatory activities are significantly changing the world's aquatic biomass, and in particular whether these activities are reducing the biomass of economically valuable species.

Although the arguments above indicate that it may be the case that fishing does not reduce *total* biomass, it is undoubtedly true that fishing can deplete a natural population, whose biomass in consequence will be well below its natural level. This has already happened for a number of species; for example, the biomass of Antarctic blue whales is certainly far smaller now than it was, say, in the early 1940s. If, however, all fishing were eumetric and took from each population only its surplus production, there would be no reduction of biomass. Even if economic and other considerations called for, from each species, a catch composition which involved removal of more than the surplus production of the natural population, the biomass of the population at stabilized exploitation would not necessarily be greatly reduced. In fact, the effect of eumetric fishing should be to maximize to productive capacity of the population. At the same time, as argued above, changes take place in the system from which the catch is taken, and these tend to offset (in terms of community biomass) the removals by fishing. It seems a logical deduction that, if fishing mortality were distributed throughout a community in such a way as to bear on each biological component in proportion to its biotic significance in the community, there could be a maximization of the community productive capacity. At this point we may refer to Michael Graham's illustration of a lawn, to distinguish between standing crop and productive capacity: a rank overgrown lawn may have, at one instant, a greater mass of vegetable matter per square yard than a neat mowed lawn, but the total amount of grass taken from the latter in a year may be far greater (and certainly much more palatable) than the amount of grass that could be cut from the overgrown lawn at the end of the year. This gives us another principle to bear in mind; it is not a standing crop biomass in which we are interested, so much as the capacity to produce biomass.

Despite such optimistic views of what could be done with fishery resources, the present condition of many fisheries, and trends generally observable, do not support such optimism. Fish stocks in various parts of the world have been reduced severely; and the trend observable everywhere, to increase the efficiency of fish searching and catching, and to increase the quantity of equipment so as greatly to increase fishing effort, makes it likely that the number of reduced stocks will be increased. Let it be clear at this point that reduction in itself is by no means objectionable; on the contrary, it is a necessary concomitant of exploitation: what is objectionable is reduction of a degree to cause a stock to be unable to use its ecological situation as well as it might and, hence, to yield less than it could.

Recent developments in the International Whaling Commission are significant in this regard. It is already an established pattern to regulate whaling by setting a limit to the catch, by specifying when and where whaling can be conducted, and by prohibiting capture of whales below certain sizes, or in certain conditions. In 1960, the Commission initiated action to obtain an assessment of Antarctic whale stocks by modern methods of population analysis, and has made a half-commitment to regulate whaling operations in conformity with the results of the assessment. At the same time, the countries that carry out pelagic whaling in the Antarctic have been negotiating a system of quotas, as percentages of the total allowable catch. These several measures, if given effect, will add up to a scheme of fishery management to give rational utilization of these stocks. They will ensure that the catch will be of a size and composition such as the stocks can sustain, and will reduce the risk that the plan may be frustrated by competition between whaling fleets. Although this would be an admirable result, it perhaps will not go far enough; we do not yet know what is happening in the rest of the community of which the whales are part—we do not know whether there are effects elsewhere in these systems about which something should be done, either in the sense of repair, or of drawing benefits being offered.

Man as disturber: Pollution and related activities

Under this heading we consider human activities: first those which cause a change in the character and quantity of materials carried into aquatic systems, either by runoff or by any other means, and secondly those which involve the use of explosives and construction of dams, which physically may cause changes in natural systems.

It is to be emphasized that we are considering here none of the activities to which the ascription "cultivation" may apply.

Through geological periods, the principal direction of movement of materials as between land and water has been from land to water; only at times of major tectonic movement, when land masses have been lifted from the sea floor, has there been any return from water to land. The activities of man over the past few millennia have, if anything, increased the transport in the direction from land to water, and the transport of material from water to land by fishing must, even at its present level, be a relatively minor element in this sequence of events. In the past century there has been a vast increase in the transport of materials from land to water as a consequence of human activities. A tremendous increase in the silt load carried by rivers has followed from the erosion caused by agriculture, de-forestation, and similar activities. In addition, the tremendous increase in population has led to vast increase in the quantities of sewage and effluents carried into natural water systems. A considerable proportion of this load of silt, sewage and effluents is of potential value to natural aquatic systems; and although much of it is lost into the great stores of silt and ooze in abyssal regions, nevertheless, in the balance sheet of nutrient materials, the primary productive systems of the waters of the world can presumably be sustained at steadily increasing levels.

In contrary sense, some of the effluent materials are of destructive nature, sometimes leading to a complete extermination of entire ecosystems. The effect of this, of course, counteracts the trend to biomass increase that might be expected to follow from other run-off processes.

Dill and Kesteven (3) summarized the effects on aquatic organisms in inland waters of water and land-use practices. Such practices may affect:

1. Reproduction and recruitment, by
    - (*a*) denying access to spawning ground,
    - (*b*) destroying spawning sites,
    - (*c*) causing high mortality among juvenile stages,
    - (*d*) in more subtle ways, affecting reproductive potential.
2. Growth, by
    - (*a*) reducing food supply,
    - (*b*) denying access to feeding ground,
    - (*c*) expanding the habitat and/or increasing the biota,
    - (*d*) inducing deep physiological effects.
3. Mortality, by
    - (*a*) increasing it as a consequence of changes in the hydrological régime,
    - (*b*) causing physical damage to individual fish,
    - (*c*) causing an increase in predation and competition.
4. The composition and structure of the biota.

Dill and Kesteven then go on to discuss the ways in which deleterious effects may be minimized, and how in many cases the opportunity given by the changed conditions may be seized to bring about an increase and improvement of the biota. The latter measures fall within the scope of the activities of man as modifier, discussed below; but if one were to attempt to strike a balance, putting on one side the losses caused by these activities (allowing for some repair work), and putting on the other side the gains made by using new or changed bodies of water in new ways, it would be difficult to say where the greater weight would lie at present.

Although the use of explosives must mean the destruction of some aquatic life, it is probable that these effects are strictly localized and in most cases transient.

Man as modifier: Positive intervention

To repeat something said earlier, the magnitude of any biological system is basically determined by the level of nutrient supply available to the primary producers, and the quality and intensity of illumination. Consequently, it would seem that anything that man could do to increase the average level of nutrient supply at any particular situation, and to increase the intensity and improve the quality of illumination, would establish conditions suitable for the enlargement of systems and acceleration of their processes.

In inland water, especially in enclosed bodies of water, the application of such measures is already of proven practicability. Efficient fish farmers normally employ methods whose objective is to increase the average level of nutrient supply. This is done in some cases by draining and cultivating the bottom of ponds. In other cases it is effected by the application of inorganic and organic fertilizers. In still other cases it is effected by an encouragement of growth of plant life, which subsequently is converted by natural processes or artificial action into organic fertilizer.

The possibility of action of this kind in larger and in open systems is less in proportion to the magnitude of the system. Nevertheless, experiments have been carried out in large inland bodies of water and in enclosed arms of the sea. The results of these experiments do not derogate the basic principle, although they show, first that a serious problem of magnitude is involved, and secondly that considerable engineering and technological problems will have to be overcome. Suggestions have also been made that the spreading of rare elements and of biotics would have a critical effect.

The most productive areas of the seas, at present, are those where nutrient material from the bottom or in suspension at great depths is brought to the surface, either by ploughing action of wind-driven water movements, or by transport by upthrusting currents of water from the deep. Suggestions have been made that such ploughing and up-welling, and the consequent enrichment of surface waters, should be brought about artificially. A number of engineering solutions to this problem have been suggested, such as the use of explosives, and the use of thermal energy either drawn from the sun or provided by atomic or nuclear power. Suggestions also have been made for the use of large thermal pumps, and of turbulence artificially induced by setting up physical barriers such as a screen of heavy chains in particular situations.

The provision of increased nutrient supply is, however, only the initial step to be taken in any project to promote increased production. To draw benefits of such increased nutrient supply it will be necessary to ensure that plant life will be present at the site of enrichment able to grow and to use the nutrients. This, of course, presents no problems in the case of enclosed bodies of water; but in the case of open systems, especially of the sea, intricate problems of biological and technological nature would have to be solved. The sowing of enriched areas with suitable plankton might be practicable. Again, in order to draw benefit from an increased phytoplankton bloom, steps would have to be taken to ensure that populations of herbivores would be available to graze on the phytoplankton, and then the various stages of carnivores would have to be present in appropriate succession.

All of the foregoing measures can be taken in enclosed bodies of water; but although experimental and practical operations can indicate the level of increase of production that such measures would permit, no estimate could be made of the magnitude of aquatic biomass that could be built up in enclosed waters at present. This is because, first, there does not yet exist an inventory of enclosed waters; secondly, man is still creating enclosed bodies of water and could continue a long way further, especially by the reclamation of swamp areas; thirdly, the status of existing enclosed bodies of waters is not known, so that it is impossible to say what improvement of them could be effected; fourthly, the utilization of enclosed bodies of water in this fashion will involve decisions having reference to political, economic and other considerations. An estimate could be made of what, theoretically, could be produced from existing bodies of water under one set of conditions intended to bring production toward maximum; but, on the one hand, there are, no doubt, many patterns by which production could be maximized, and whether any pattern would be realized would depend on the economic and political considerations. As to the introduction of such measures in the seas, it can only be said that all the foregoing reservations would apply to a considerably greater degree.

The foregoing line of thought suggests a sequence of direct intervention in natural systems, intended to modify, increase and improve them comprehensively; and although reservations are made as to the economic desirability and the political advisability of giving effect to them, considerable advance could be made with a régime of lesser measures. Here we are dealing with measures that might be adopted to promote the expansion and improvement of the biological components of open ecosystems. First, steps could be taken to give advantage to favoured elements of these systems. Species of economic importance can be introduced to particular waters. Species also can be transplanted from situations that are unfavourable (because of crowding or other conditions) to situations where food supply is better or prevailing conditions are favourable in some respects; again, such favoured species of economic value can be reared to an age at which, on release in natural surroundings, they will have a better chance of survival than they would have had if they had passed through all the juvenile stages in those natural surroundings. Again, improved varieties, or hybrids, could possibly be bred for particular situations and their stock maintained either by planting from hatcheries; or in favourable situations they might even establish themselves in their new situation and maintain themselves by natural reproduction. Favoured species also could be increased by direct intervention, which would be intended to reduce the pressures on them from predators and competitors; the elimination, or at least reduction, of what in this sense are virtually weed species could promote under certain circumstances a considerable expansion of the population of favoured species (5).

This last idea is an aspect of the proposition that eumetric fishing could assume modes other than specification of the effort and catch in exploiting a single species population, by being extended through the community. In its present form, the theory of fishing accepts (or assumes) prevailing values of parameters of the population (growth, reproduction, natural mortality), and provides methods of setting fishing mortality at a level the stock can sustain. In this form it relates to populations of one or a few species; and, although its results may be adjusted in the light of evidence of effects appearing in these populations as a result of effects produced in other biological components of the system, no provision is yet made for positive action, by controlled fishing, to influence the processes of a community as a whole. A more directed strategy of fishing might seek to reduce severely those species which make no contribution to the processes of a food web comprising economically valuable elements; whilst contributing species (although not economically valuable) could be brought to greater production by selective fishing.

Possibilities of such action in the sea

Human action can reduce biological systems, or improve and increase them. As predator and disturber, man, unless he controls his actions, does damage; but if he controls his actions, both he and his environment can draw benefit from them. As modifier he can create, cultivate and successfully husband his resources. All this he can do in enclosed bodies of water (ponds, dams, etc.). What can he do with open systems (large lakes, rivers, the seas)? Let us take each of the activities in turn.

The regulation of fishing, and the application of eumetric fishing (both in its present form and in the suggested deeper form) obviously have meaning for open systems. Reduction of weed and pest species is by no means an impracticable proposition: already it has been done with some measure of success in the control of starfish on oyster beds.

Minimization of pollution and of its deleterious effects is also possible, but taking advantage of such effects would be less easy. A. C. Simpson once suggested, I have heard, that it should be possible to take greater advantage of the enrichment of the sea at sewer outfalls.

Taking advantage of erosion run-off would probably be in the same class as mobilizing nutrient stores on and just above the sea-floor; that is to say, theoretically some of the suggested things could be done, but apart from questions of cost, no one could yet design such an operation which could, on biological grounds, be assured of success.

As for cultivation, several examples already point the way. I.C.E.S. has recently decided that there is prospect of profit in plaice transplantation and probably also in hatchery work for this species. Russian workers report the introduction of sturgeon and salmon species to situations they did not previously inhabit and, in the case of the sturgeon, the introduction of food organisms as well. Canadian workers report success in breeding a new variety of salmon. These operations are moves away from the seashore where, for centuries in various parts of the world, various forms of cultivation have increased the supply of seaweeds, sponges, oysters and mussels. Perhaps the principal lesson to learn from these examples is that each represents an attack on a particular problem to achieve a particular end.

The bases for realization of such possibilities

In the face of available evidence, to say that the question is not "can these things be done?" but "will it be worth while to do these things?" or "when will it be worth while?" is probably not mere optimism; and then the problems become—how to determine which things would profitably be attempted in the immediate future, and what would have to be done before they could be attempted with confidence?

Four sets of problems present themselves here. First, those relating to information; second, those relating to technological and engineering features of contemplated operations; third, those relating to economic aspects of contemplated projects—chiefly the ratio of the expected cost to the value of the hoped-for benefit; fourth, those relating to international interest in the area of a contemplated project. It is sufficient here to single out these sets of questions whose implications must be obvious; it would be futile to attempt to particularize them and unnecessary to attempt to generalize principles with regard to them.

Conclusions

Thus, if in natural state these systems are in more or less stable condition (except when cataclysmic events occur) and, if anything, show a trend, however slight, toward covering the earth more fully and using materials and energy more efficiently; and if it is true (as it appears to be) that man can halt and reverse this trend, or accelerate it, in particular systems, and conversely can materially modify communities, exterminating them or replacing them completely: then the only logical conclusion is that the biomass of the future is likely to be just so much more or less than it is now, as man makes it to be.

In that case, we need not speculate about such biomass, nor can we hope to forecast it by extrapolation from existing systems; instead, targets may be set for adopted programmes and the prospects of hitting them may be assessed. But, since we do not know what the wishes and decisions of future generations will be, and we cannot bind those generations, we may leave them to the situations they may meet, and ourselves concentrate on the problems we create by our own wishes and decisions.

DISCUSSION

DR. GEORG BORGSTRÖM (U.S.A.): I have arrived at figures of the same magnitude from an entirely different starting point. Working down from primary production, the margin is still narrower. The final figure for secondary carnivores is reduced to approximately 300 million metric tons, and for commercial fishes to approximately 60 million metric tons. This finding makes me conclude that there must exist more feedback at each conversion level than I previously thought. Perhaps the non-living organic matter of the sea may be utilized by fish, which would allow a greater harvest in future. Also, in going from present catches to primary production, the present Atlantic catch allows for only three and a half conversion steps from one trophic level to the next, while in the Pacific it is about five steps. Productivity chains in the sea are longer than this; therefore, such comparisons are misleading. We need to correct our perspective on these questions and recognize the fundamental differences between agriculture and fisheries. The primary proteins involved in present fishery production in the Pacific are approximately ten times larger than the total primary protein in world agriculture.

DR. W. M. CHAPMAN (U.S.A.): Potential harvest of the seas is greatly underestimated. Preliminary calculations in our area of the Pacific suggest a potential fivefold increase over present catches as being more realistic, and it might be as high as tenfold. No world fishing area is intensively fished except immediately around the Japanese home islands, where there is a great variety and enormous production. The North Sea is heavily fished, but only for selected species. In the California current the most abundant species is the anchovy, but only a few thousand tons are caught. The saury is next in abundance, but not fished at all; nor is hake, the third most abundant species. In California, our most important fishing state, we are not harvesting our most abundant species. Basic productivity in West Africa and in various areas of the Indian Ocean is very high, but harvesting methods of low efficiency are used. Peru has increased production from 100,000 lb. to 3 million lb. in just a few years. It is calculated that this catch can be increased two to three times more. The Bering Sea was not thought to be highly productive, but Russians and Japanese are now taking a million tons per year of bottom fishes. Therefore, estimates by Graham and

Edwards are very much on the low side. This subject is very important and deserves further investigation.

DR. ROBERT L. EDWARDS (U.S.A.): Our estimate of second level carnivores may be low; but we disagree that production can be increased by a factor of ten. Perhaps we could achieve this by eliminating one of the upper levels of the predator pyramid. Migration of sea lamprey into the Great Lakes has reduced the lake trout stocks to very low levels; but higher yields of other species have come about now that the predatory lake trout has gone. It will be interesting to see what happens after the sea lamprey has been eliminated and trout stocks increase again. Obviously, at present we do not have enough data to make a sound decision.

DR. W. M. CHAPMAN (U.S.A.): It is obvious that, where such differences of opinion exist, there is not sufficient knowledge to make a good estimate. We must obtain a better understanding of the transfer of nutrients from the depths to the photosynthetic layers. At present there are enormous areas of upwelling where no real fishing exists. We are not basically in disagreement, but are labouring under lack of knowledge.

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Acknowledgements

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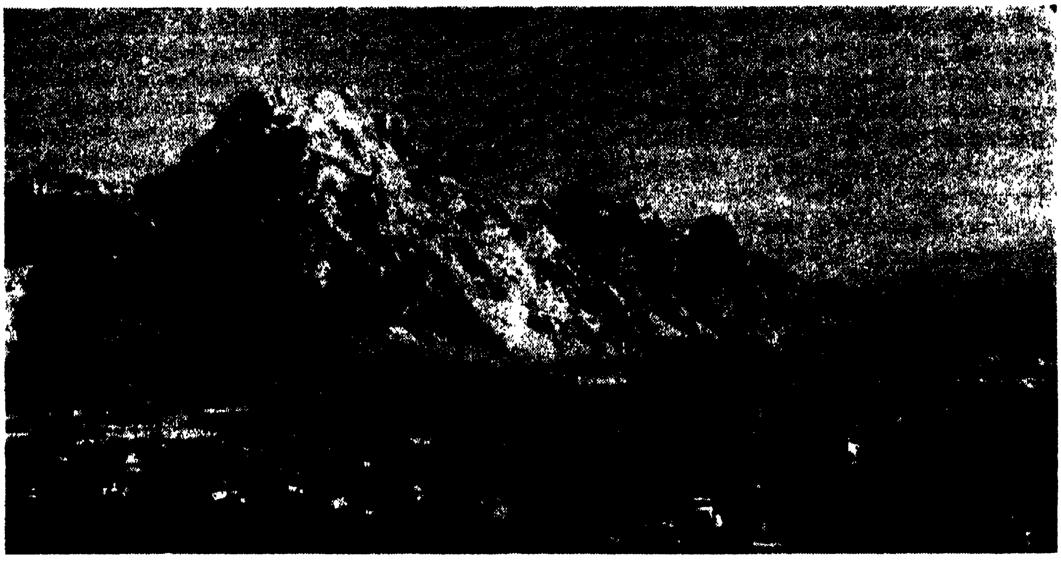

One of the great fisheries of the world is that for cod off the Norwegian coast. This arises from the nutritious food supply there provided by the intermixing of tropical and arctic waters. In good years the catch of cod exceeds 400,000 metric tons and is distributed to world markets in both fresh and processed form. Modern techniques under scientific direction have largely revolutionized both the catching and processing sides of the industry in recent decades. Formerly some 4,000 small craft employed 20,000–30,000 fishermen; now bigger craft with fewer men are used. *Photo: Courtesy Atlantic Ocean Fisheries.*

IMPORTANCE OF FISHERIES PRODUCTION AND UTILIZATION IN THE FOOD ECONOMY

by

G. MESECK

The disquieting facts of world hunger and protein deficiency are reviewed, and the need to encourage fisheries exploitation as one solution is stressed. Figures are given on world distribution of calories and animal protein. Comparisons are made between agricultural and fisheries contributions.

Knowledge of sea and freshwater fisheries is reviewed. Figures are given on development of world fishing yields 1900–60, with discussion of future estimated yields. FAO statistics on world fish catch by continents since 1953 are given. Suggestions are made for an international report service for fishing conditions and scientific data, to improve fisheries exploitation. The promising potential of freshwater and brackish-water ponds is discussed.

A continent-by-continent and nation-by-nation outline is given, to determine whether estimates of future fisheries production are realistic. Outstanding examples of national improvement, as seen in Peru, are discussed.

Figures on utilization of fish yields are reviewed. The large proportion of fishing yields devoted to fishmeal production is mentioned, and the recent development of deep-freezing in advanced countries. The possible use of fish flour for human consumption is touched on, and there is a discussion of freeze-drying, which is believed may revolutionize the fishing industry.

IMPORTANCE DE LA PRODUCTION ET DE L'UTILISATION DES PECHES DANS L'ECONOMIE ALIMENTAIRE

On rappelle les faits inquiétants de la faim et de la déficience protéique dans le monde, et on souligne la nécessité d'encourager, comme l'une de leurs solutions, l'exploitation des pêches. On présente des chiffres concernant la distribution mondiale des calories et des protéines animales, et on compare les contributions respectives de l'agriculture et des pêches.

Nos connaissances en matière de pêche maritime et continentale sont passées en revue. On présente des graphiques du développement de la production des pêches de 1900 à 1960 en discutant les estimations futures de la production. Après avoir rappelé les statistiques de la FAO sur les quantités mondialement pêchées par continent depuis 1953, on présente des suggestions pour un service international d'informations sur les conditions et les données scientifiques des pêches, destiné à améliorer l'exploitation des pêches, et l'on examine le potentiel prometteur des étangs d'eau douce et d'eau saumâtre.

Un examen, continent par continent et nation par nation, cherche à déterminer si les estimations des productions futures de la pêche sont valables. On commente des exemples saillants de progrès national, comme celui du Pérou.

On examine les traits généraux des productions du poisson, en mentionnant la grande proportion de ces productions qui se trouve transformée en farine de poisson et le développement récent de la cryo-dessiccation dans les pays modernes. Après avoir abordé l'usage possible de la farine alimentaire de poisson pour la consommation humaine, on parle de la cryo-dessiccation qui pourrait révolutionner l'industrie des pêches.

IMPORTANCIA DE LA PRODUCCION PESQUERA Y SU APROVECHAMIENTO EN LOS ASPECTOS ECONOMICOS DE LA ALIMENTACION

Se reseñan las inquietantes realidades del hambre y escasez de proteínas en el mundo, y se recalca la necesidad de fomentar la producción pesquera para remediarlas. Se dan datos relativos a la distribución de carlorías y proteínas animales en el mundo. Se comparan las aportaciones de la agricultura y la pesca.

Se mencionan los conocimientos actuales de la pesca marina y de agua dulce. Se dan datos sobre la producción pesquera mundial desde 1900 à 1960 y se examinan los rendimientos estimados futuros. Se presentan estadísticas compiladas por la FAO relativas a la pesca por continentes desde 1953, y se hacen propuestas para crear un servicio de información internacional de condiciones pesqueras y comunicaciones científicas para mejorar la explotación pesquera. Se examina el prometedor potencial de los estanques de agua dulce y salobre.

Se hace un estudio por continentes y países para determinar si las estimaciones de la producción pesquera futura son realistas. Se analizan ejemplos extraordinarios de mejoras nacionales, como han ocurrido en Perú.

Se reseñan datos de aprovechamiento del pescado y se mencionan la gran proporción de la pesca que se destina a la fabricación de harina y los avances de la congelación en los países adelantados. Se cita el empleo de la harina de pescado en la alimentación del hombre, y se describe la criodesecación, que puede revolucionar la industria pesquera.

I. THE ECONOMIC IMPORTANCE OF FOOD

(a) As a food source, the waters of the world have been underestimated for a long time. This has been particularly true when seas and freshwater areas were compared with farmed land as a food supplier. This underestimation has hindered ocean and fisheries research and the development of the fishing industry.

The substantial food reserves awaiting exploitation in the earth's water were far too little appreciated. This failure was customary in both national and international thinking. There was a Fisheries Division in FAO—and a quite active one—but it was small, its budget was small, and it had a rather shadowy existence. In future it will be more and more appreciated, both within FAO and among member nations. Projects such as the Freedom from Hunger Campaign and the technical assistance program for underdeveloped countries will also continue to be acclaimed (11, 42, 44).

Recently, the world's waters have come into their own as a potential food supply. Prominent statesmen and scientists have been stressing the importance of the sea in this respect. To top it all, they have called attention to the need for better sea exploration and exploitation, which are much more important for mankind than space research (29). These are wise words.

(b) A great many books have been written on the problem of whether food production can, in the long run, keep up with the explosive growth of human population (population bomb) (Fig. 1) (1, 2, 5, 23, 24, 27, 28, 42, 43, 44). There are some dark forecasts.

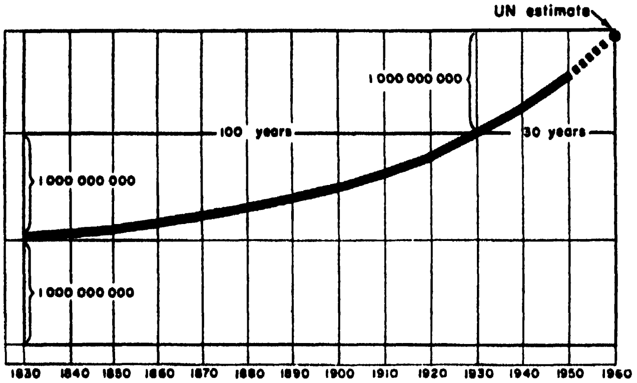

Fig. 1. World population from 1830 to 1960. Source : (43).

But voices also rise, claiming the earth could nourish 20 billion, if the great potential of science and technology could be used sensibly. There are Neo-Malthusians, but just as many optimists who are convinced that food production could increase as population rises (1).

It is true that agricultural progress in several continents has already caused production to exceed consumption. But no one can avoid the bitter fact that the number of starving people has also increased considerably since pre-war days. The following table (Table I) demonstrates the point convincingly.

TABLE I

World distribution of calories and animal proteins for pre-war, early post-war, and recent periods
(per person per day at the retail level)

	Per cent of the total population covered[1]		
Nutrient	*Pre-war*	*Early post-war*	*Recent*
Calories (in numbers)			
Over 2,700	30·6	27·8	21·6
2,700–2,200	30·8	12·7	19·0
Under 2,200	38·6	59·5	59·4
Animal protein (g.)			
Over 30	22·1	17·2	19·5
30–15	18·9	24·8	19·8
Under 15	59·0	58·0	60·7

[1] Comprising approximately 80 per cent of the world's population.

Source: This table was appended to a lecture prepared by P. V. Sukhatme, Director, FAO Statistics Division, on 11 August, 1960.

About 60 per cent of the world's population receive fewer than 2,200 calories per day, and 80 per cent must be content with less than 30 g. of animal protein per day. Over 60 per cent have a daily ration of less than 15 g. animal protein. These are disquieting figures, and it is no secret that millions of people die from malnutrition, owing to shortage of animal protein even today.

Beside the total hunger, however, the partial hunger mainly indicated by an *extreme shortage of animal protein* causes great trouble (5, 24, 27, 42, 43, 44). We know that in many countries of the world the greatest part of the population does not receive more than 5 to 10 g. of animal protein per day, and that expectant and nursing mothers are suffering from this shortage and its terrible consequences (35). But it is also known that this protein deficiency can quickly be cut down or even removed, in places where the sea and its protein resources are nearby. It is nothing less than grotesque to know that coastal people are suffering from hunger when, almost at their front door, large stocks of fish exist in the sea, virtually unexploited. This anachronism has been found over and over again in several countries and continents (11).

(c) In food production on land, it is quite possible to increase the amount of carbohydrate and fat within a relatively short time by soil cultivation, fertilizing, plant cultivation, etc. It is, however, considerably more difficult, and needs much more time, to produce more meat and other animal protein. Moreover, there are many areas where, for climatic and other reasons, animal breeding is either impossible or limited. At any rate, most experts are of the opinion that a special bottleneck will develop with the production of animal protein, when food production has to be increased to meet requirements of the growing population, and that it may be difficult to overcome this problem (21, 35, 45). There are, however, some scientists who quite recently suggested that a person can also exist with an animal protein ration of below 30 g. per day. Up to now, this has been considered the minimum need. They speak of overestimating the essential amino acids and of underestimating the non-essential amino acids. They point out that in Asia many people get along, consuming small amounts of animal protein, but sufficient vegetable protein. Nevertheless, we shall have to distinguish between people's mere ability to survive and their mental and physical efficiency. At any rate, it has been proved that people who receive too little animal protein are more or less unfit for mental and physical labour. They are generally living in a state of lethargy and apathy, and are particularly exposed to all kinds of diseases.

(d) It is vital to close the gap in animal protein supply in the underdeveloped countries. This gap cannot be closed, or can be closed only very slowly, by increased agricultural production. But by activating the fisheries and drawing on the first-class protein sources of sea, lake, river and pond, an extraordinary blow can be struck in the fight against world hunger (5, 23, 24).

In the tropical zone and the southern hemisphere, this large protein source is almost untouched. But at long last it is being recognized, and we may hope that fisheries' importance in the food economy will enjoy more and more notice. Our target must be the world's hunger areas in the tropics and southern hemisphere; but we should not forget there are northern areas where hunger is a problem too (1, 2, 11, 17, 20, 29). There is no need to go into detail here about the relation between adequate nutrition, efficiency and population income (Table II).

TABLE II

Income and consumption of cereals and protein per head in selected countries 1957–58

Country	*Income*	*Total Consumption of cereals as food, feed, seed, etc., in terms of grain and husked (or milled) rice*	*Cereals for direct human consumption in terms of flour and milled rice*	*Protein for human consumption*	
				Animal	*Total*
	(1)	(2)	(3)	(4)	(5)
	U.S. $	.........*kg. per year*......	....	...*g. per day*...	......
United States	2,164	646	67	66	94
Canada	1,431	929	71	62	95
United Kingdom	960	413	85	51	87
France	839	375	110	49	96
Italy	406	304	142	25	76
Japan	250	218	157	15	67
Mexico	234	218	147	16	66
Brazil	218	214	106	18	67
U.A.R.: Syria	169	257	162	12	73
Egypt	112	235	188	13	79
Pakistan	77	173	151	8	45
India	60	144	124	6	47

Source: (43).

Note: Data in column (2) refer to "domestic disappearance", that is, to production *plus* opening stocks and imports and *minus* exports and closing stocks.

In short, I re-emphasize that a comparatively small effort put into fisheries development will quickly result in improved standards of living and nutrition, if the pre-requisites are fully recognized. This has been proved possible by impressive examples. Peru is brought to mind, and some African and Asian countries.

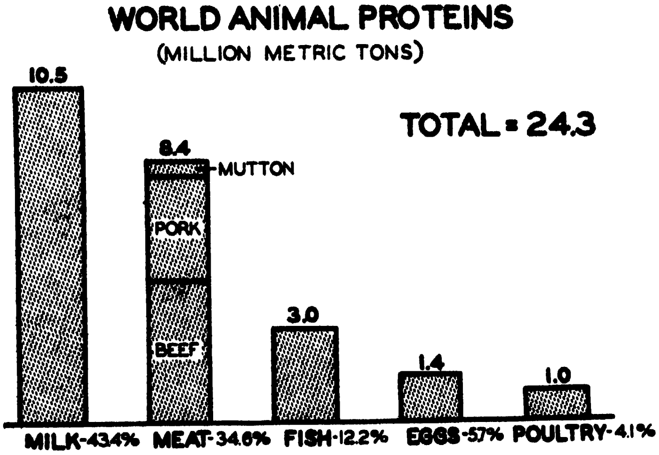

Fig. 2. The simplest way to measure fish against other animal proteins is to compare, on a global basis, the total amount of various animal proteins. Here fish immediately emerges as a major factor—12·2 per cent of the whole. And, most significantly, one must notice that fish is a primary source of animal protein to nutritionally low standard nations; that is, it feeds—or, at least, fills the gap between starvation and subsistence—far more millions than does either milk or meat. More than two-thirds of the world's meat and milk is consumed by fewer than 600 million people. But the number of humans to whom fish constitutes more than half of their average daily animal protein exceeds 1,500 million! Source: Borgström (40).

(e) Up to now, fisheries contribute only about 12 per cent to the supply of animal protein for the human population (Fig. 2). According to FAO statistics (Second

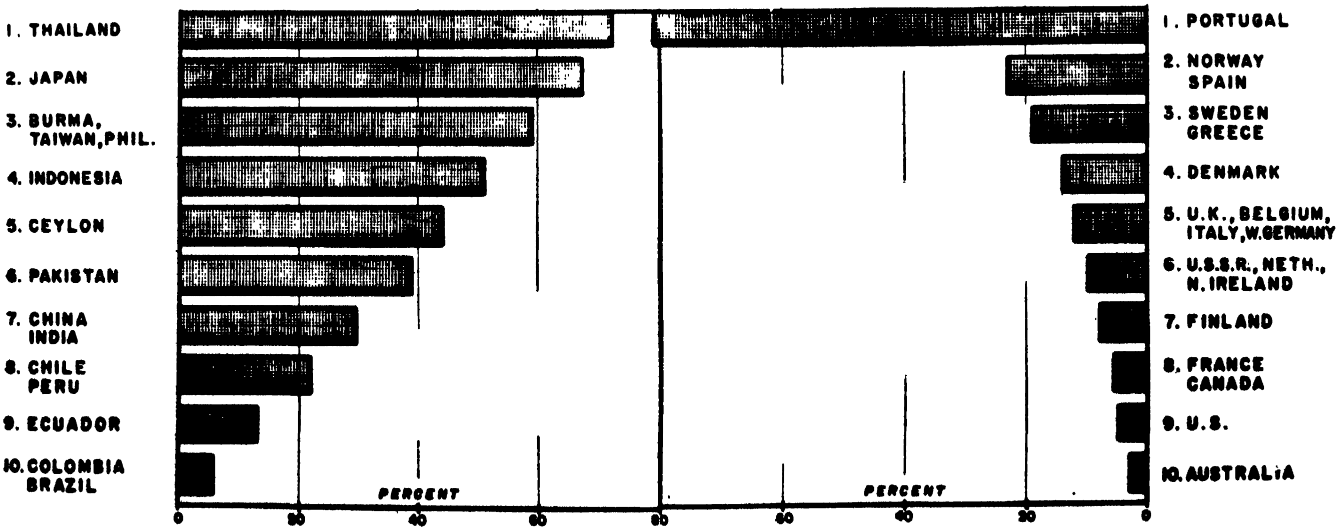

Fig. 3. This graph shows that percentage of the population of various countries which could be supported by the protein in the fish normally consumed. Note the high percentage of population supported by fish in the Asiatic and some South American countries, compared with the lower proportion in European countries (with the exception of Portugal), North America and Antipodean areas. Fish is fundamental in supporting at least 1,500 million people in the areas indicated, whereas in what can be loosely described as the Western World it is of importance to only some 680 million people. Source: Borgström (40).

World Food Survey—November 1952) (32), the percentage shares of the continents are as follows:

	per cent
Far East	19·1
Near East	2·5
Africa	3·5
Latin America	3·5
Europe	7·8
North America and Oceania	1·0

The value of these figures today is limited, since they were computed about ten years ago.

Another publication (1961) shows how much animal protein is obtained per day from fish and fish products in various countries (40) (Fig. 3).

The biological value of the flesh of fish and other marine animals is highly estimated by nutrition-physiologists. Fish protein contains relatively great portions of methionine, lysine and tryptophan. The German nutrition-physiologist, Kühnau, judges the total value of fish protein so high, that he classifies it immediately after the value of mother's milk. The fats in fish and various vitamins and minerals are also considered particularly valuable for nutrition (13, 21).

II. FISHING YIELDS

(a) Of the 510 million square kilometres of the surface of the globe, 361 million square kilometres (about 71 per cent) are ocean. The terrestrial surface, including freshwater areas, amounts to only 149 million square kilometres (about 29 per cent). About 155 million square kilometres of the sea area are in the northern, and 206 million square kilometres in the southern, hemisphere. Only a comparatively small part of the vast oceans are being exploited for fisheries. The sea fisheries mainly concentrates, for the time being, on so-called shelf areas (shallow areas up to 200 m. in depth): about 30 per cent of the shelf areas are in the southern hemisphere, and about 70 per cent in the northern hemisphere (7, 8, 12).

During the last two decades, the slopes of the continental shelf, mainly those of the northern hemisphere, have been fished more and more intensively, to a depth of 500 to 600 m. In depths over 600 m., only some experimental fishing has been carried out. The so-called "high seas" outside the continental shelf, by far the greatest part of the seas, are not yet quite developed for the fishing industry, although fishing for shoal fishes has become more important in recent years. Primarily, these are tuna, bonito and species of the clupeide family.

Ocean research in shelf areas has been carried on more intensively since the beginning of the century. But comprehensive research-results in high-sea areas are still lacking. Generally speaking, *ocean research* is considerably in arrears, compared with other fields of natural science. This is not because the scientists concerned did not have the necessary enthusiasm. Our *knowledge* of the extent of the *living resources of the sea is still very incomplete.* It will be one of the great tasks of the human race to increase efforts for a systematic exploration of these living resources. Already there are many signs that this is going to happen. First, it will be essential to intensify international co-operation, for no country alone will be able to provide the scientists and money required for comprehensive, world-wide research programs of sea exploration.

Conditions of life and production in freshwater areas are far better known. Here, regular economic methods, similar to animal breeding in agriculture, can be adopted.

Generally speaking, our knowledge of the earth's waters has already reached such a degree that we should certainly be able some day to double the present production of our fisheries.

(b) Fishing is one of the earth's oldest industries. It had considerable economic impact centuries ago on a much smaller world population. But the industry did not get into its stride until the use of steam power, the motor, and the invention of the bottom trawl during the second half of the last century. There has been more progress in fisheries within the past 50 years than in the previous 3,000.

Nevertheless, the fishing industry is still at a stage which agriculture had reached about 1,000 years ago. Despite all technical progress in designing fishing vessels and gear, the sea fisheries still have the character of hunting. In other words, it is still basically an attempt at indiscriminate capture, without any previous systematic measures and without any management of fish stocks in the real sense of the word. But as Dr. Finn, Director of Fisheries Division of the FAO, has expressed it, fisheries must someday be managed like a farming enterprise, so that the fish stocks can be cultivated and herded on the pasture, just as the farmer herds his cattle (11). It is, however, doubtful whether this can be reached for many species of fish. But there are hopes that for certain species successful results may be attained in this direction. These considerations are by no means based on utopian ideas (29).

(c) *Since the beginning of the century the fishing yields of the world have increased tenfold.* In the last decade the growth rate was greater than that of many other foodstuffs. I do not intend to quote a lot of statistics, which can be seen in many publications, particularly those detailed fishery statistics of FAO. Nevertheless, I must mention some figures to support my explanations.

Until 1948, we did not have proper world fisheries statistics. Since then, the Fisheries Division of FAO has regularly published a *Yearbook of Fishery Statistics,* and the data have improved from year to year (31). Considering the difficulties still connected with the collection of statistical material, the quick preparation of statistics should be especially appreciated. In the Fisheries Division of FAO, however, one is quite aware that fisheries statistics are still rather incomplete, and that their collection and elaboration needs continued improvement. I suppose that statistics are to be considered as minimum figures. Probably, sea fisheries statistics are more reliable than those of freshwater fisheries. Statistics of freshwater fisheries have to be based even more on rough estimates.

As regards the *development of the fishing yields of the world* from 1900 to 1960, the following figures are available (rounded off to million tons):

1900–1910	4
1924	10
1932	10
1934	14
1936	17
1938	21
1947	18
1948	19
1953	25
1955	28
1957	31
1959	35
1960	38

Source: (6, 9, 10, 14, 16, 31).

Some experts believe an increase to about 100 million tons to the end of this century might be possible without difficulty. The FAO supposes that, until 1980, about 60 to 70 million tons could be produced (Finn 11). But they have marked this prognosis with a question mark, although the growth rate of about 31 per cent between 1934 and 1959 suggests such an expectation.

I do not think I am unrealistic if I consider the possibility of increasing the world fishing yields to 1970 as follows (million tons):

1962	41
1964	44
1966	47
1968	51
1970	55

As in the past ten years, the further production increases will vary according to geographic areas. In the 1955–59 average, about 74 per cent of the world *sea fisheries production* was in the northern hemisphere, about 21 per cent in the tropical zone, and about 5 per cent in the southern hemisphere. In 1960, this picture had already changed in favour of the tropical area and the southern hemisphere. Among other things, this is due to the extraordinarily rapid increase in the fishing output of Peru. The share of the northern hemisphere is particularly great. The largest continental areas are concentrated there, serving the greatest part of the world population.

In Table III the fishing yields of the world are given by continents for 1953–57 (average) and 1958–60:

TABLE III

World catch by Continent: average 1953–57, 1958–60
(million metric tons)

	Average figures			
	1953–57	1958	1959	1960
World Total . .	**28·19**	**32·13**	**35·60**	**37·73**[1]
Africa . . .	1·75	1·98	2·10	2·23
America, North .	3·95	3·99	4·27	4·05
America, South .	0·82	1·60	2·91	4·32
Asia . . .	11·55	14·22	15·38	16·06
Europe . .	7·63	7·61	8·06	7·89
Oceania . .	0·11	0·11	0·12	0·13
U.S.S.R. . .	2·38	2·62	2·76	3·05

Source: (31, 34).

[1] Freshwater 4·37, northern hemisphere 22·40, tropical zone 9·20, southern hemisphere 1·76.

The fishing yields of the world are distributed to the individual continents as follows (per cent):

	1938	1954	1959	1960
Africa . .	3	6	6	6
North America .	15	15	12	11
South America .	1	3	8	11
Asia . .	46	40	44	43
Europe . .	27	28	22	21
U.S.S.R. . .	8	8	8	8

Source: (31).

From 1954 to 1960 the share of Africa remained constant, whereas that of North America slightly decreased, that of South America more than doubled, that of Asia slightly increased, while the European share decreased and that of U.S.S.R. remained the same. From 1954–59 the growth rate of the sea fisheries in the northern hemisphere amounted to 21 per cent, in the tropical zone to 59 per cent, and in the southern hemisphere to 23 per cent. In the tropical zone and the southern hemisphere the growth rate of production was greatest in the Pacific Ocean (Eastern-central, South-eastern), amounting to 280 to 300 per cent (31).

The share of *freshwater fisheries* in the total world production was from 1955 to 1960 between 10 and 12 per cent. The growth rate of 44 per cent was considerably greater than that of the sea fisheries (32 per cent) and was even greater than the growth rate of the fishing yields of the world (33 per cent). In Asia the growth rate of 75 per cent was above the average. Among fisheries experts the opinion prevails that the production of freshwater fisheries could be increased more rapidly than that of sea fisheries.

(d) Considering the hitherto insufficient knowledge of optimum fisheries production, it appears rather daring to estimate the future production by continents. If I suppose that until 1980 a world production (marine and freshwater fisheries) of up to 70 million tons might be attained, I come to the following estimates of possible optimum yields, under consideration of the present growth rates and other viewpoints (million tons):

Africa	8
North America	9
South America	10
Asia	22
Europe	10
Oceania	3
U.S.S.R.	6
	70[1]

With the very complicated phenomena of life in the water, the non-foreseeable hydrographic, biological and meteorological changes, and the innumerable factors on which the fishing activity depends, I am certainly aware of the fact that the above figures are only a very rough estimate which I myself regard with reservation. You may well ask the basis for these considerations. Although I have studied all available publications and other material for a long time, and know the fishing industries in several continents from experience, I may quite well have overlooked some data. I think, however, one should attempt to make such estimates if one wishes to gain a conception of the possibilities for fisheries development. In the following I shall try to explain my ideas as clearly as possible.

(e) A great number of scientists have investigated the biomasses of the seas and freshwater areas, and there is the general opinion that the waters produce at least the same amount of organic substances as the terrestrial area (7, 8, 36, 37, 38). Productivity of the waters is dealt with in this Conference by qualified scientists, so I don't need to mention it here in detail. Thus I can go on to discuss the factors affecting those organisms which can be utilized economically; this means the final products in the metabolism of the waters.

The living resources of the various sea areas depend on the conditions of life essentially influenced by the *movements of the water masses* (7, 8, 12, 35). Particularly important are: the upwelling of deep-water layers rich in nutritive substances to the upper regions, the coinciding horizontal currents of various origin and temperature, as well as the exchange of water between upper and lower regions of the sea in northern and southern latitudes, when the upper layers cool down in winter.

This exchange of water is frequently designated as "sea plough" of extraordinary effect, especially as it ranges up to 4,000 m. in depth (12, 29).

The investigation of the *currents of the sea*, and the various effects of chemical, hydrographical and biological factors connected therewith, is of vital importance for the future development and extension of sea fisheries. Unfortunately, there are still very great gaps, which can only gradually be filled by close international co-operation (19).

The fisheries are always specially productive where rapid currents contribute to the enrichment of the upper water layers by supplying nutritive substances, thus furthering the development of a rich marine fauna and flora. Such sea areas with high biological productivity exist in all areas of the world. Examples are the Benguela current off the African coast; the Canarian current off Northwest Africa; the Humboldt current off Chile and Peru; the Californian current off the west coast of the United States; the coincidence of the Oyashio and Kuroshio currents off Japan and the Kuriles; the influence of the Kuroshio current on the waters off British Columbia; the coincidence of the Labrador current and the Gulf current off the Grand Banks near Newfoundland; and various other currents like those off the Norwegian coast, West Australia, in the Arabian Sea, etc. The areas, where the water masses are whirled up most, are located in the eastern boundary-currents of the East Pacific, in the Atlantic and in the Indian Ocean; but they are not limited to these waters, and can also develop in the central sea areas as, for instance, in the border zone between the Equatorial counter-current and the North Equatorial current—both in the Pacific and Atlantic.

For commercial fisheries it would be very valuable if sea currents, and their influence on the conditions essential to life of the fish stocks, could be brought some day under systematic scientific management. It should be possible to develop a kind of international report service similar, for instance, to the report service of the world organization for meteorology. By continuously collecting important chemical, hydrographical and biological data and reporting them to a central office, where they would systematically be prepared and evaluated, reliable advice could be given to the commercial fisheries for their operations. This would not only help to improve the exploitation of the fish stocks, but also considerably increase the economic results from the fishing industry. The great dependency of the fisheries on unknown natural factors and changing natural conditions affect their profits to such an extent that the great economic risk over and over again results in setbacks having an adverse effect on steady development. Even agriculture is very dependent on natural conditions and natural changes. The dependency of the fishing industry, however, is still very much greater, and discourages the industry again and again from making greater investments.

An *international report service* giving information on the fishing conditions would no doubt diminish the economic risk. Better management of fishing fleets would be possible. The most suitable fishing gear could always be used. Moreover, it would be easier to establish teamwork, still missing in almost all parts of the world. Even within the fishing industries of the individual countries, each enterprise goes its own way, scarcely ready to trade experience or co-operate on a broad basis.

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[1] 60 marine fisheries, 10 freshwater fisheries.

Fishermen are very conventional people and cling obstinately to traditional methods. The European trawl fishery, for instance, still uses the bottom trawl as its main gear, although it has been proved long since that, at certain times of the year and for certain species of fish, the pelagic trawl is more efficient. Generally speaking, inflexibility in fishing technology is apparently hampering fisheries far too often. Bad yields caused by a wrong fishing technique are frequently explained as *overfishing*. The term "overfishing" has been much misused during recent decades. Since the beginning of this century the term "overfishing" walks like a ghost through the literature. Now may be the time to restrict this term to the scientifically and economically justified degree (19).

It cannot be denied that overfishing exists in some sea areas and for some species of fish. But one should not overlook that the lives of fish and other marine animals depend on such a great number of factors, that catches taken by men could not normally be so tremendous that they would be a serious influence. Many examples could be given with proof that natural reasons had caused the changes in the stocks; not overfishing. For instance, the decrease in the flat fish stocks of the Baltic had been traced to overfishing. Later it was found that the decrease was due to reasons which had nothing to do with fishing intensity.

Also the great anxiety about overfishing North Sea white fish stocks as a consequence of increased trawl fishing did not prove right. The discussions now dealing with the overfishing of the North Sea herring stocks should be judged just as sceptically. The total herring yields from the North Sea have certainly fluctuated in recent decades. But considering a longer period, they have even increased. The so-called statistics of fishing efforts are by no means convincing evidence. Merely an inefficient fishing technique, not flexible enough to pursue the everchanging fish locations, has resulted in poor production. Right in the North Sea it has been proved in recent years that countries which used a more adaptable fishing technique caught more herring than ever.

In fishing techniques, however, it is not only the type of gear that counts. It has been proved more and more that width of mesh in the trawling gear has a decisive influence on success. At any rate, there is no doubt that the fishing yields in the North Atlantic would be substantially greater if fishing gear with larger meshes were generally used. This is quite apart from the fact that only fish of commercial size would then be caught, which could be utilized with a better economic profit.

Summarizing, I would like to state that in no part of the world have the possibilities of further increasing fisheries production been properly utilized, and that overfishing of some fish stocks may be talked of in only a few cases (11, 12, 15, 20). The growth rates, however, will be essentially greater in the tropical zone and in the southern hemisphere than in many parts of the northern hemisphere, as has already been the case during the last decade. First, better knowledge of all natural factors determining the life and size of fish stocks will be of greatest importance for a further production increase. It might be just as important really to evaluate these factors for a sensible fishing technique, using all modern physical and technical aids. In this connection we shall also have to strive gradually to go over from indirect to direct detection and finding the shoals of fish.

(f) The *freshwater areas*, whose production conditions are already much better known than those of the sea, have so far contributed in most continents only a small percentage to the supply of animal protein for human consumption. Generally speaking, these waters not only include the natural lakes, ponds, rivers and artificially constructed waterways, but also the river estuaries, closed lagoons and bays of the sea (brackish-water areas) as well as the paddy fields submerged for 3–8 months each year. Considering that the freshwater areas of the world have a surface area of 500 million hectares, and the cultivated rice fields of the world only 100 million hectares, one gets some impression of the reserves still existing for the production of fish (Table IV).

TABLE IV

Productivity of various freshwater and brackish-water areas
(in kg. per hectare and year)

Area	*Average production* kg.	*Attained maximum yield* kg.
Natural waters (without fish farming)		
Lake Victoria (East Africa)	1·6	—
Lake of Halstatt (Austria)	6·5	—
Lake Tiberia (Israel)	40·0	—
Lake Karoon (United Arab Republic)	104·0	—
Lake Edku (United Arab Republic)	285·0	—
Lake Tempe (Indonesia)	800·0	—
Freshwater ponds (with fish farming)		
U.S.A.	170	375
Federal Republic of Germany	200	800
Yugoslavia	370	1,400
Indonesia	1,000	8,000
Israel	1,650	5,000
Republic of Congo[1]	2,000	9,300
Brackish water ponds		
West Java	178	—
Central Java	155	—
East Java	311	—
France	300	—
Celebes	680	—
Sumatra	833	—
Philippines	333	800–1,200
Formosa	1,063	1,800–2,000
Singapore	—	1,110
India (Coast of Malabar)	—	1,000
Cochin	—	1,700
Wet ricefields		
Malaya	135	—
Japan	145	2,250[2]
Tanganyika	110	—
Indonesia	139	—

[1] Previously Belgian Congo.
[2] With additional food.

Source: (2, 12, 33).

Up to now, mainly the natural fish stocks of the freshwater and brackish-water areas are being exploited. The possibilities of systematic modern fish breeding methods, however, are yet too little used. But it has been proved that properly managed *freshwater ponds* produce considerable yields per hectare. Of course, climatic and other conditions play a part. While in Europe average yields of 200–400 kg. per hectare and maximum yields of 800–1,400 kg. per hectare are not rare, in Indonesia, Israel and Congo average yields have been attained of 1,000–2,000 kg. and maximum yields of 5,000–9,000 kg. per hectare.

Also *in brackish-water ponds* fish breeding can be carried on successfully. This is particularly known in the Far East (Indonesia, Sumatra, Philippines, Formosa, India—Malabar coast). The average yields fluctuate between 150 and 1,000 kg. per hectare.

On wet *paddy fields* average yields of 100–150 kg. per hectare can be produced. But it is known from Japan that maximum yields of even more than 2,000 kg. have been reached. One has computed that the area of cultivated rice fields (sc. 100 million hectares) could produce about 5 million tons of fish, based on a modest yield of 50 kg. per hectare. This alone would equal the present production of the freshwater fisheries of the whole world (12).

(g) If we examine the individual continents to find out whether the estimates on the optimum possibilities of the fishery production until 1980 (see p. 28) are well founded, the following may be outlined (Fig. 4):

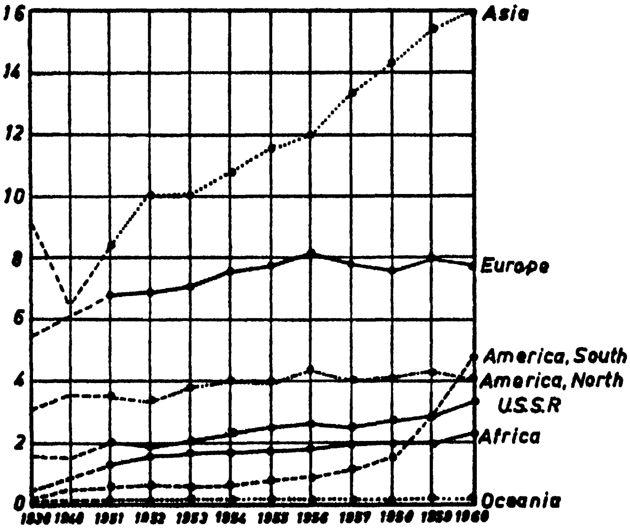


Fig. 4. World catch. (Live weight, million metric tons.) Source: (12, 14, 36).

(*i*) **Africa** (4, 12, 25, 30, 31, 39, 46)

The African sea and freshwater fisheries have been markedly underdeveloped up to now. Except for some countries (for instance Republic of South Africa/Southwest Africa, Angola and Morocco) the sea fishery is limited to a primitive coastal fishery which, owing to unfavourable climatic conditions and inadequate channels of distribution, is only supplying in effect the coastal population.

From reports made by FAO fisheries experts, the results of various fisheries expeditions and experience from the assistance programmes show that yields of the African sea fisheries could still be greatly increased. For some years the development of the tuna fishery and the fisheries for several species of the clupeide family have become increasingly important (for instance in Senegal, Ghana, Guinea). The most insignificant sea fishing obviously takes place off the African coast in the Indian Ocean. Here, too, one expects future expansion. At first, however, it might be necessary to increase the hitherto poor knowledge of fishing conditions.

A thorough investigation of the biological productivity of all the African coastal waters is urgently needed.

Even the *freshwater fishery of Africa* could be substantially expanded if proper economic measures were taken. Most of the natural waters indicates a great productivity, so far as investigations have been made. Moreover, experiments have shown that *fish farming* can successfully be carried out in large parts of this continent. As already mentioned, a remarkable growth rate has been attained in the fish ponds of the Congo.

For many African countries the quick production of greater amounts of animal protein by their own means is not only a central problem of the food economy, but also a prime question of economic importance. Up to now, large amounts have had to be spent on the import of dried fish, a heavy burden on the budget.

(*ii*) **North America** (4, 12, 30, 31, 39)

In North America the fisheries of the **United States** and **Canada** are the most advanced. Nevertheless, further development on both Atlantic and Pacific coasts is thought quite possible. The fishing yield from the Gulf of Mexico could be considerably increased. Great possibilities are also suggested for increasing the freshwater fisheries. Figure 5 gives the average U.S.-catches of fish and shellfish from 1926 to 1959, showing the

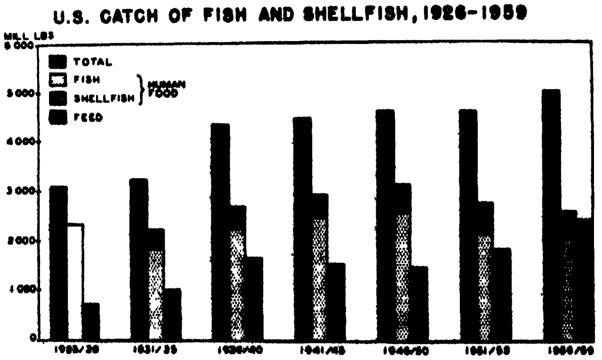


Fig. 5. U.S.A. catch of fish and shellfish, 1926–1959. Source: Borgström (39).

gradual increase in the industrial fishery and the decreasing production of fish for human food. On the whole, there might well exist the pre-requisites for doubling the present fishing yields in the United States and Canada. While in **Canada** the small population hampers the quicker development of the fisheries, this field of the food economy in the U.S.A. is in strong competition with agriculture and, indirectly, with other commercial fields of economy. This is partly due to the agricultural surpluses in the U.S.A.; but in New England the better incomes in the commercial economy also have a negative effect.

In the Central American States, the fishing industries are still very much underdeveloped. The present fishing yields of Mexico could be at least trebled. It is to be hoped that, in line with the assistance programmes for underdeveloped countries, greater progress will be attained in the next few years on the Pacific coast as well as on the Gulf coast. The fisheries of the **smaller Central-American States** are also underdeveloped, although the shortage of animal protein is especially great and the economic structure of these countries is relatively one-sided (monocultures). An assistance to the development of fisheries would be very useful here.

(*iii*) **South America** (4, 12, 16, 22, 31, 39)

As compared with other continents, the growth rate of the South American fishery was particularly great in recent years. First, the **Peruvian** *sea fishery* developed to a degree unparalleled in the world. The fishing yield increased from 160,000 tons in 1954 to 4·0 million tons in 1961 (Table V). The progress of the Peruvian sea fishery is a good typical example of how quickly and with what relatively simple means the food reserves of the sea, completely overlooked for a long time, can be mobilized (Fig. 6). The Peruvian fishery is particularly favoured by the upwelling of deep water masses, rich in nutritive substances, in the area of the Humboldt current. Such upwellings, however, also exist in other sea areas. Unfortunately, their effect and importance are far too little known at present.

TABLE V

Fish catch and fish meal production in Peru, in 1,000 tons

	1948	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*	*1958*	*1959*	*1960*	*1961*
Fish catch . . .	48	137	148	176	213	297	483	930	2,100	3,501	4,000
Fish meal production .	—	9	12	16·5	20	31	64·5	127	332	558	640

Source: Yearbook of Fisheries Statistics (31) and Desarollo della Pesca Peruana en 1961.

On the Pacific coast of South America the sea fisheries of **Chile** and **Ecuador** are also progressing. From 1954 to 1959 alone, the fishing outputs of Chile have doubled and those of Ecuador have trebled. Experts believe that the whole Pacific fishery of South America can be considerably expanded. This does not only refer to the anchoveta fishery, but also to the tuna fishery.

In view of the prevailing shortage of animal protein, which great parts of the population in the Pacific countries of South America are suffering from, it would be essential to see that greater quantities of the catches would be utilized for direct human consumption. The fact that, for instance, 90 per cent of the Peruvian fishing yields are processed into fish meal for animal food, may be more or less necessary for a transition period, but it must not become permanent.

On the Atlantic coast of South America **Brazil** is now the most important fishing country. The fishing yields of **Argentina** and **Uruguay** are not yet particularly important. In the Caribbean zone, the fishery of **Venezuela** has steadily developed in the recent years. In **Columbia**, after an increase, fishing yields have again been declining.

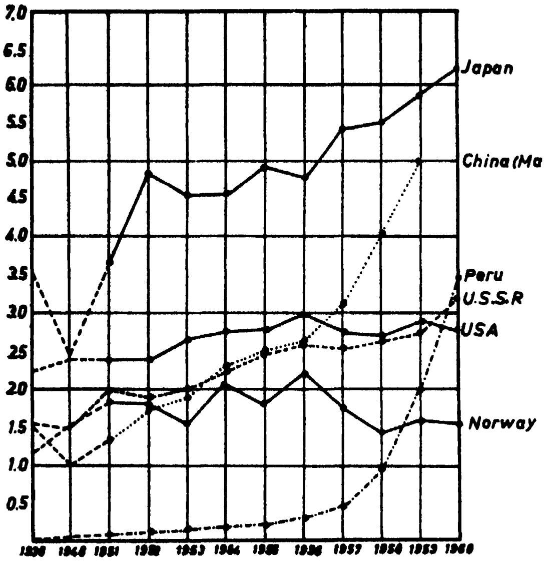
Argentina and Brazil have considerable shelf areas along their long coastlines. Moreover, numerous rivers carry waters rich in nutritive substances to the sea. On the wide shelf off the Argentine coast there are comparatively few hindrances, so that an intensive trawl fishery would be quite possible. There are estimates indicating that an optimum fishing yield of 5 million tons per annum could be reached in Argentina, and of 3 million tons in **Brazil**. It is difficult to judge if these figures are realistic, particularly since we still know very little of the biological productivity of the sea areas off Argentina and Brazil. Therefore, I personally make a more cautious prognosis; but I still believe that the fishing yields of Argentina could be increased to 3 or even 3·5 million tons, and those of Brazil to 1 or even 1·5 million tons per annum.

The hitherto small fishing yields of Argentina might finally be due to the fact that the population already can be provided with sufficient animal protein from the important cattle industry of the country. Conditions in Brazil are different, where a great number of the inhabitants get too little animal protein.

On the Caribbean coast the fisheries of Venezuela and Columbia might be quite capable of development. It is believed, for instance, that the remarkable sardine stocks occurring off the coasts of both countries are by no means properly exploited. The possibilities for a further intensified shrimp fishery are also considered favourable.

Comparatively little is known about the freshwater fisheries of South America. The figures contained in the FAO statistics are certainly too small. A regular commercial fishery, however, obviously takes place only in the estuaries of the large rivers and in some larger lakes. For the rest, freshwaters are apparently only occasionally exploited.

(*iv*) **Asia** (3, 4, 12, 16, 17, 18, 20, 31, 33, 41)
The main share in the fishing yields of the world (43 per cent) goes to Asia. The greatest fishing nations are **Japan** and **China** (mainland), of which the yields were in 1959 between 5 and 6 million tons with a further increase in 1960. Japan has an important fishery in remote sea areas, extending already to the Pacific, the Indian Ocean and some parts of the Atlantic (off the African and South American coasts). It is to be supposed that this remote fishery will develop further (Fig. 6). Japan intends to increase the fishing yield to about 7·4 million tons by 1970.



Source: (12,36)

Fig. 6. Catch of fish, crustacean, molluscs, etc., for the 6 largest producing countries. Source : (12, 36).

Considering the heavy increase in population, the unfavourable food conditions and the extreme shortage of animal protein, one can suppose that this country will develop its fisheries with the greatest attention.

Other important fishing countries of Asia are, up to now, **India, Indonesia, North** and **South Korea, China** (Taiwan), the **Philippines, Pakistan, Thailand, Vietnam** and **Malaya.** It is known that in all these, and even in other countries, the freshwater and sea fisheries could contribute substantially more to the supply of animal protein for the population than has been done. The food reserves of the sea are in no case sufficiently exploited, despite the extreme shortage of animal protein prevailing in more or less all Asiatic countries. For instance, the fishing yields of India and Pakistan could be increased several times. Beside technical and organizational difficulties, religious taboos also have a negative influence there.

According to reports from German experts it would be possible at least to treble the fishing yields of the sea fisheries of Thailand.

The total output of aquatic products in Mainland China probably exceeded five million tons in 1960 (Table VI). It is therefore still far below the potential yield, estimated at over seven million tons (Table VII).

TABLE VI

Fisheries output in Mainland China, 1936 and 1949–60

Year	*Total output (1,000 metric tons)*	*% increase over previous year*	*Marine fisheries*	*Inland fisheries*
			(1,000 metric tons)	
1936	1,500	—	1,000	500
1949	448	—	300	148
1950	910	103	610	300
1951	1,300	42·8	870	430
1952	1,666	28·1	1,110	556
1953	1,900	14	1,265	635
1954	2,294	20·7	1,530	764
1955	2,518	9·7	1,680	838
1956	2,640	4·8	1,760	880
1957	3,120	18·1	2,080	1,040
1958	4,060	30·1	2,560	1,500
1959	5,020	23·6	2,760	2,260
1960 (plan)	5,800	16	—	—

Source: Reports of Mainland China's State Statistical Bureau and *Hsinhua* (bimonthly, published in Peking), 6 April, 1960 (41).

TABLE VII

Estimated potential output of Mainland China

	Metric	*Tons*
Marine fisheries		
436,000 sq. miles at 10 tons per sq. mile p.a.		4,360,000
Inland fisheries		
Rivers and lakes—8·7 million hectares at 0·15 tons per hectare p.a. . . .	1,200,000	
Ponds and paddy fields—3·7 million hectares, of which 1·6 million hectares utilized for fishery at 1 ton per hectare p.a.	1,600,000	2,800,000
Total		7,160,000

Source: Minister of Aquatic Products at 7th Session of the National People's Congress on 5 July, 1957 (*Hsinhua* report) (41).

Comparison of Tables VI and VII indicates that recent efforts have brought the output of inland fisheries very near maximum potential. Of course, various breeding methods and enlarged fishing area may raise their output to about 3 million tons, which probably can be achieved within the next two or three years. Due to progress in farming and water conservancy works, many previously uncultivated and dry places now abound in fish. Furthermore, the breeding area has substantially increased, thanks to the adoption of harbour-breeding and the expansion of the area of beach raising. The growth of marine fisheries, however, is still probably 30 per cent below maximum potential. The growth of output of marine fisheries so far has been relatively slow, which can be explained by the shortage of capital resulting in the lack of fishing vessels of larger sizes and the low degree of mechanization (41). Quite extraordinary possibilities exist in wide areas of Asia for *fish farming in rice fields.*

The experience of FAO and several European countries under the assistance programme for fisheries development reveals quite distinctly that the Asiatic countries suffering from hunger could help themselves successfully just by developing their fisheries.

(*v*) **Europe** (4, 12, 15, 16, 18, 20, 30, 31, 39)

The European fishery is, up to now, well advanced. It is already operated so intensively, that the increase in the yield can only continue slowly. From 1954 to 1959 the growth rate of the European yield was thus substantially lower as compared with other continents. But it should not be overlooked that the European yields, especially from the North-east Atlantic, almost doubled from 1938 to 1959.

The fishing areas of Europe are relatively better explored than those of other continents, although there still are rather large gaps. European fisheries have made special progress in fishing techniques, although the development varies from country to country.

Although climatic conditions are not too favourable, the European freshwater fisheries are generally quite progressive. This does not only refer to the more or less intensive management of natural waters, but also to fish farming.

In contrast to some experts, I am of the opinion that European fisheries could be further developed. Apart from the fact that fishing techniques in some countries are too one-sided, I believe there still are fishing resources in some areas of the European northern seas which, up to now, have been exploited either scarcely or not at all.

(*vi*) **Oceania** (4, 12, 30, 31)

The fishery of Oceania has been unimportant. This, however, is not due to a lack of biological productivity in those sea areas, but to the fact that the fisheries have been regarded as less interesting in view of the small population of that continent. As far as it can be judged, however, this condition might change in the coming decades. Anyhow, it is known that Australia in particular intends in future to explore and to develop the living resources of the sea with greatest attention. It can be concluded, from the few publications on it, that the prerequisites for fisheries development, primarily the pelagio fisheries, are more favourable than was supposed.

(*vii*) **U.S.S.R.** (4, 12, 30, 31, 39)

The U.S.S.R. has approximately doubled the fishing yields since pre-war days. For years, great efforts have been made in the U.S.S.R. to improve ocean and fisheries research as well as fishing techniques. The success achieved in the Atlantic Ocean cannot be denied. In the Far East also the U.S.S.R. fisheries have expanded. Moreover, its endeavours to improve its freshwater fisheries cannot be overlooked. Figs. 7 and 8 demonstrate the development in the various fields of Sovietic fisheries from 1913 to 1960.

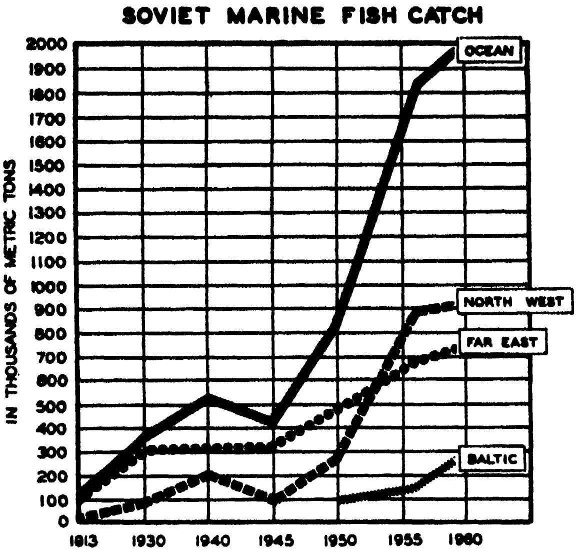


Fig. 7. Soviet marine fish catch. Source: Borgström (39).

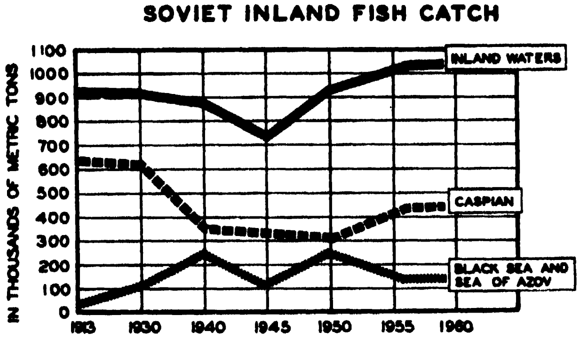


Fig. 8. Soviet inland fish catch. Source: Borgström (39).

Despite a strict control of the fisheries, and the employment of combined fishing and factory ships and factory vessels with independent fishing vessels, the fishing yields have shown only a small increase between 1954 and 1959. With the large vessels, partly or fully mechanized, some difficulties apparently occurred at first, which had or have still to be overcome. But the latest news about the present U.S.S.R. building programs indicates that the method of operating large combined fishing and factory vessels, and factory ships with independent fishing vessels, will consequently be continued. Moreover, vessels are designed for the fisheries in tropical waters. It is also known that experimental U.S.S.R. fisheries have repeatedly been carried out in African waters. The efforts of the U.S.S.R. obviously aim at further future fisheries development and at constant expansion of operational areas. The enormous efforts in the fisheries and ocean research serve the same purpose. According to the present Seven Year Plan the fishing yield should be increased to 4·64 million tons by 1965. Nevertheless, to meet the growing demand for fish and fish products in the U.S.S.R., it is necessary to increase the annual catch of fish and marine animals, whales, etc., to 7–7·5 million tons. For that purpose sea fisheries have to be further expanded to remote oceans, and freshwater fisheries have to be even more developed. The output from the large water reservoirs, for instance, is estimated at 200,000 tons per annum. Moreover, 800,000 tons of freshwater fishes (as carp, trout, etc.) may be expected from extensive pond farms which should be established in the wide rural areas.

(h) Of course, increase in fishing yields does not only depend on biological productivity of seas and freshwater areas, but on specific economic and financial conditions. This refers, among other things, to the educational standard of the fishermen, to the technical possibilities of the fisheries, the utilization of the catches and the marketing conditions. Many difficult problems arise from these items which can only gradually be solved.

In many parts of the world, where either no fishing or only very primitive fishing takes place, one cannot, within a short time, reach a development corresponding to the fisheries of Europe or North America. One cannot intensify the fisheries in one direction without knowing how and in which way marketing is possible. Experience with fisheries assistance has more or less clearly shown that there are no reliable standards. Only after previous careful investigations can it be decided in any special case which methods are the best to start and develop a fishing industry.

In many cases it proved that it was at first useful to process most of the increasing yields into fish meal. This is a relatively simple process, which brought considerable economic success even under climatically unfavourable conditions (for instance in Angola, South Africa, Peru, etc.). Nevertheless, this one-sided way of utilizing the increasing fishing yields can usually only be a transition phase. The aim of any fisheries development must finally be to utilize the greatest possible part of the catch for direct human consumption.

III. UTILIZATION OF FISHING YIELDS (31, 34, 39)

(a) From 1957 to 1960, about 40–43 per cent of the fishing yields of the world have been consumed fresh, 8–9 per cent have been frozen, about 20–24 per cent have been salted, dried or smoked, about 9 per cent have been canned, about 13–20 per cent have been used in various processed forms (Table VIII). These figures, however, do not mean that 83–87 per cent of the fishing yields of the world are used for direct human consumption. It has to be remembered that, beside the direct processing of fish into fish meal and fish oil, large quantities of fish offal are utilized in the same way. At the International Meeting on Fish Meal in March, 1961, in Rome, it was stated that, in 1960, about 10 million tons of the fishing yields of the world (almost 25 per cent), either as whole fish or fish offal, have been reduced to fish meal and fish oil. But there are many fishing countries where over 50 per cent of the fishing yields, either as whole fish or fish offal, are processed into fish meal and fish oil. In some countries the greatest part of the landings is used for that purpose.

(b) Fish and other marine products deteriorate very rapidly. Therefore, they can be kept for human consumption only for a short time, particularly under unfavourable climatic conditions. The conservation of the catches, therefore, has always played a great part, as only in this way a longer-keeping quality, better storage and transport quality could be attained. Even today, the oldest methods of preservation—i.e. *drying, salting and smoking*—are very important to the fishing industry. The use of wet ice and dry ice for keeping fish fresh is generally known, as well as canning in airtight containers. Moreover, many chemical and biochemical processing methods for preserving and preparing fish products have been developed.

(c) Quite recently, the *deep freezing* of fish has become more and more popular. The greatest progress in that method has, up to now, been achieved in the United States. In Europe and other parts of the world, deep freezing has also been adopted to a greater extent. This method has become indispensable for the growing fisheries of remote areas.

Deep freezing of fish, however, requires comparatively great investments (cold chain), and running costs from the fishing ground to the consumer. Therefore, it is only suitable for those countries where the population has already reached a higher standard of living.

(d) For several years, the nutritive-physiologists have dealt with the problem of whether *protein concentrates* (fish flour) could be produced for human nutrition (21, 35). Even under unfavourable climatic conditions this can be easily transported without special difficulties. During the International Meeting on Fish Meal in March 1961, in Rome, the present experience with this was discussed in detail. The report on that meeting contains all the information, so that it is not necessary to mention the details here. I only wish to point out that production of protein concentrates, which can be supplied to the population either directly or in connection with other food, are of great importance to countries with underdeveloped fisheries, which are usually also those countries suffering from hunger.

(e) A new method of food preservation is the *freeze-drying* method (45). In Great Britain and in the U.S.A., large-scale scientific investigations on freeze drying have already been carried out for a long time. In Aberdeen (Scotland) an experimental plant has been installed, where considerable investigations on the theoretical bases and practical utilization of this method have been made. Moreover, a so-called accelerated freeze-drying

TABLE VIII

Utilization of catches

(in live weight equivalents)

Disposition	1955	1956	1957	1958	1959	1960
			in million metric tons			
Total world catch	**28·3**	**29·8**	**30·8**	**32·1**	**35·6**	**37·7**
Estimated quantities used for:						
Marketing fresh	12·2	12·5	13·2	13·8	14·9	15·1
Freezing	1·9	2·2	2·4	2·7	3·0	3·4
Curing	7·1	7·3	7·3	7·3	7·2	7·3
Canning	2·5	2·7	2·9	3·0	3·3	3·5
Reduction to meal, oil, etc.[1]	3·6	4·1	4·0	4·3	6·2	7·4
Miscellaneous purposes	1·0	1·0	1·0	1·0	1·0	1·0
			in percentages			
Total world catch	**100**	**100**	**100**	**100**	**100**	**100**
Marketing fresh	43	42	43	43	42	40
Freezing	7	7	8	8	8	9
Curing	25	25	24	23	20	19
Canning	9	9	9	9	9	9
Reduction to meal, oil, etc.	13	14	13	14	18	20
Miscellaneous purposes	3	3	3	3	3	3

Source: (31).

[1] Offal included.

method has been developed, reducing the drying period considerably.

Meanwhile, Messrs. Vickers Armstrong (South Marston) Limited have designed Accelerated Freeze Drying —A.F.D.—plants for practical use. They can be used for fruit, *fish*, meat and vegetable. By means of this method all humidity, or about 5/6 of the original weight, is removed. The dried foodstuffs can then be stored in plastic wrappings for years at normal temperature. The product is light as a feather and crumbles in the hand. It recovers its original form when immersed in water, and it looks again quite natural. It is reported that foodstuffs processed by freeze drying can be cooked relatively quickly.

In the food industry of the U.S.A. and several European countries, a greater number of large capacity freeze-drying plants are already in operation. The greatest part of the processed products is used for soups ready for cooking, for which a quick recovering is specially important.

In 1960, for instance, in San Carlos, Texas, the production of freeze-dried shrimp meat was started. That plant is at present processing over 2,000 kg. of shrimp per day. They are said to be of excellent quality. Anyhow, the product has been readily accepted by the consumers, as it competes well with deep-frozen shrimp, as far as flavour and consistency are concerned. The same good results have been achieved by the Bundesforschungsanstalt für Fisherei (Federal Institute of Fisheries) in Hamburg with a number of experiments with food shrimp. This institute also made experiments with fish which have been equally successful.

In the Federal Republic of Germany the firm of Maggi-GmbH of Singen (Lake of Constance) installed an experimental freeze-drying plant for foodstuffs for commercial use. The production is used for further processing of soups ready for cooking. The freeze-dried products (vegetable, meat and *fish*), however, still had some defects. As they quickly absorb air, the oxygen contained in the air may easily cause some changes. The careful packing of freeze-dried foodstuffs is therefore a substantial pre-requisite for completely maintaining the nutritive value.

Even with the operation of the freeze-drying plant itself some difficulties occurred, which however will be overcome by technical improvement.

The commercial use of freeze-drying plants, however, is still somewhat restricted by the very high costs of these units. The high selling price of freeze-dried foodstuffs also hampers, for the time being, the marketing of these products.

As far as can be judged, however, the food-physiological and technological problems of freeze-drying have apparently been solved in principle. It is to be expected that the firms manufacturing such plants will very soon be in a position to sell them at reasonable prices. This might probably be the case, as soon as serial manufacture is possible.

Freeze drying may, in many respects, cause a really revolutionary change in the fishing industry. The method deserves the greatest attention as, owing to the remarkable reduction in weight, costs of packing and transport are saved, and moreover a long storage quality is secured under any conditions. These advantages could perhaps even offset the increased production costs. For fish marketing, one would possibly in future not need much expensive equipment for maintaining quality, and marketing would be essentially less complicated. For all fishing countries in warmer and hot zones (especially for underdeveloped countries), where also traffic and marketing equipment are less developed, freeze drying could be an ideal method to supply the population with fish even over the longest distances. Even air transport in areas with poor traffic would perhaps be justified from the economic point of view.

Further research work of technological development to bring the product within the purchasing power of average families, especially in developing countries, should be encouraged.

I am convinced that by means of freeze drying the living resources of the sea could be utilized for mankind to a far greater extent than I have been able to describe in the course of this article.

IV. SUMMARY

(a) Better ocean research and increased exploitation of the living resources of the sea are of greatest importance in view of the explosive growth of human population. The number of starving people has considerably increased in the last decade, and the extreme shortage of animal protein has been particularly felt. It is rather difficult to eliminate this bottle-neck. The protein reserves of the seas and freshwater areas, however, can be mobilized more quickly than in agriculture. The waters can therefore render extraordinary help to the Freedom from Hunger Campaign. The countries suffering from hunger also belong to the undeveloped areas, and any assistance for development can only be successful if people have enough, and good enough, food. Animal protein plays the most important part, and it is therefore essential to utilize the still unexploited resources of the seas and freshwater areas.

(b) Since the beginning of this century the fishing yields of the world have increased ten times and amounted, in 1960, to about 38 million tons. It has been considered possible to increase the production to 55 million tons by 1970 and to 70 million tons by 1980. While the greatest fishing yields have been produced up to now in the northern hemisphere, this may in future change in favour of the tropical zones and the southern hemisphere. Substantial possibilities exist here for a rapid increase in production. This has been proved by example. The opinion predominates that the production of the freshwater fisheries can be increased more quickly than that of the sea fisheries.

In sea fisheries international co-operation is particularly important. An international report service giving information on the prevailing fishing conditions would considerably diminish the economic risk, and would also help to make the fishing methods more efficient and more variable. Despite all technical progress, fishing methods are still too one-sided. Ever-changing locations of fish require a greater variety of effort. It is necessary to change gradually from indirect to direct detection of fish shoals.

The term "overfishing" must finally be restricted to a scientifically and economically justified degree. The effects on the fish stocks are usually over-estimated, compared with natural factors that can be little influenced. Overfishing may perhaps be recognized for some sea areas and for some species of fish.

Up to now, many freshwater areas are exploited very little or not at all. By fish farming in ponds and rice fields very great yields could be produced.

In all continents a considerable increase in fisheries production is possible. This could be done particularly in Africa, Asia and South America, but also in other areas.

Until now most fishing has been carried out on the continental shelf area, and the high-seas fishing is only slowly developing. The exploration of these sea areas and the improvement of pelagic fishing methods, therefore, call for increased attention.

(c) The utilization of fishing yields has changed during the last 20 years. Deep freezing, for instance, has become more and more popular. But, up to now, almost 25 per cent of the total fishing yields are still processed into fish meal and fish oil, and are thus lost for direct human consumption. In view of the extreme shortage of animal protein in many countries it must be attempted in future to utilize the fishing yields as much as possible for direct human consumption and to restrict the production of fish meal and fish oil to offal. It is, however, admitted that, in the gradual development of fisheries in the undeveloped countries, a great portion of the catches must be reduced to fish meal and fish oil during the transition period.

In the fish processing industry, deep freezing and the production of protein concentrates should become increasingly important. The greatest attention should be given to *freeze drying* which, in many respects, may cause a truly revolutionary change in the fishing industry. By means of the freeze-drying method the food resources of the seas could be utilized more quickly, and to a greater extent for the human population, than may seem possible from the present point of view.

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DISCUSSION

Dr. C. L. Cutting (U.K.): I am not very optimistic about the future of freeze-drying as being the cure-all process. There is currently no scientific account of the process available. It is documented only in the trade press, which is undoubtedly optimistic and exaggerated. Fish is the *least* successful of all freeze-dried products, and I am not convinced that modifications of the process would improve its status significantly. The claim (by U.S. producers) that freeze-dried shrimp is equivalent to shrimp frozen by conventional processes suggests that U.S. commercial freezing processes and equipment are not as efficient as those in the United Kingdom. Other problems, such as standardized, simplified drying methods not employing conventional power sources, are of higher priority.

Mr. Hugo Loredo (Mexico): In Mexico it is difficult to get reasonable market reception for any processed fishery product, due to the limited purchasing power of the population. This applies to even the most simple processing methods. It is suggested that an attempt be made to increase consumption of naturally-dried fish to avoid basic economic problems involved in production, transportation, storage, etc. It is difficult to get good quality naturally-dried fish in the tropics, however, and this problem needs investigating. It has been observed that the limitations to expanded consumption are based almost exclusively on the limited purchasing power of the most numerous sector of the population, which cannot pay the price for fish that the sectors with higher income can afford. This is true, not only of fresh fish kept on ice, and salted and dried fish, but even more of frozen and canned fish, the preparation of which is at the moment very costly. For this reason, it is believed advisable to promote, among the population with limited income, an increase in the consumption of fish preserved by means of salting and drying. The process of preparing dried fish, when the technique is carried out correctly, is much less costly than the other means of preservation, and offers the following advantages: it does not require a large initial investment; it has superior nutritive value for the same commercial weight; it can be transported and preserved for long periods without affecting the cost; and, finally and no less important, it can be done in a short time without much difficulty. It should be mentioned, however, that high-quality dried fish is difficult to obtain in tropical or subtropical climates; but, as there is no desire initially to compete with similar imported products, this does not immediately constitute a serious problem

Dr. W. M. Chapman (U.S.A.) endorsed the comments of Mr. Loredo, and stated that what is restricting utilization of the resource is not abundance, but the cost of getting the product into the "belly" of the consumer. This is the prime factor. Although many "under-nourished" countries live near a "resource", they may have little means to utilize it properly on account of economic limitations.

Dr. K. K. P. N. Rao (FAO): To say that many millions are actually starving to death, not merely suffering from malnutrition, is an exaggeration. Malnutrition is quite different from starving to death. This factor should be elaborated in future collections of statistics.

While the scientist, the engineer and the practical operator have enabled advanced countries to quickly and economically process fish for human needs, other countries are only gradually evolving from methods they have hitherto employed under their conditions. One big task is to accelerate the change to more satisfactory and quicker methods. This picture illustrates the task FAO is tackling: that of spreading knowledge of better methods of utilizing fish for human food. Dr. Rudolf Kreuzer, Chief of the Fish Processing Section of Fisheries Division, FAO, visited Africa to experiment with improved methods of drying fish. The native method here shown covers four stages—sun drying of fish on the ground, then piling in stacks, next on wooden platforms and finally, in a shelter (see framework) in which, after it is covered with palm leaves, the fish will be finally smoked. In contrast Dr. Kreuzer used a simple plant consisting of a drying tunnel through which an engine and fan sucked air to dry it. By this means he produced prime quality dried fish in 24–36 hours against 10–14 days of the traditional method. (See also page 116.)

THE ROLE OF FISH IN HUMAN NUTRITION

by

B. C. GUHA

A large proportion of the world population suffers from under-nourishment, both in quantity and quality. Calorie intake per caput per day ranges from less than 2,000 to more than 3,000. Protein intake ranges from 40 to more than 100 g.; animal protein intake is sometimes as low as 7 g. per caput per day, or even less in some countries. It is no wonder therefore that protein malnutrition is prevalent in many countries, and this affects in particular young children and infants. In many countries there is a shortage in the diet of calcium and of vitamins, especially of vitamin A and members of the vitamin B group.

Fish contains proteins of high biological value, comparable with those of egg, milk and meat. The content of proteins, fat, minerals and vitamins varies between species; for instance, fat content varies from 6 per cent to 20 per cent. Fish oil has a higher proportion of unsaturated fatty acids than animal fat. It is also a good source of Ca, P, Fe, and a number of vitamins. Preservation and careful processing does not affect the nutrient value much.

Fish consumption is low in many countries, where one would expect a more liberal supply. Unless technological methods are employed for making fish and fish products available to the people without deterioration, and without considerable loss of nutritive value, their consumption cannot be increased to the extent which may be desired. The utilization of the by-products of fish processing, its scales and offal, would reduce the cost of the edible portion of the fish. This cost question is important in regard to the increased consumption of fish, as most consumers who like fish and would benefit by its consumption are quite often unable to buy fish in adequate quantities because of the price.

LE ROLE DU POISSON DANS LA NUTRITION HUMAINE

Une grande partie de la population mondiale souffre d'un taux alimentaire suboptimum à la fois en quantité et en qualité. La quantité de calories journellement absorbées par individu varie de moins de 2.000 à plus de 3.000; la quantité de protéines de 40 à plus de 100 g.; et celle de protéines animales atteint des chiffres aussi faibles que 7 g. par tête et par jour, voire moins dans certains pays. On ne doit donc pas s'étonner que la malnutrition protéique joue un rôle primordial dans de nombreux pays et qu'elle affecte particulièrement les bébés et les enfants. Dans de nombreux pays, le régime alimentaire présente un déficit en calcium et en vitamines, spécialement en vitamine A et en vitamines du groupe B.

Le poisson contient des protéines d'une haute valeur biologique, comparable à celle de l'oeuf, du lait et de la viande. La teneur en protéines, en graisse, en minéraux et en vitamines varie selon les espèces; la teneur en graisse, par exemple, varie de 6% à 20%. L'huile de poisson présente une plus grande proportion d'acides gras que les graisses animales. Elle est aussi une bonne source de Ca, P, Fe et d'un certain nombre de vitamines. La conservation et un traitement soigné n'affectent pas beaucoup la valeur nutritive.

La consommation du poisson est faible dans de nombreux pays, où l'on pourrait s'attendre à un approvisionnement plus large. A moins d'employer des techniques industrielles qui fournissent aux populations du poisson et des produits du poisson sans altération et sans perte considérable de leur valeur nutritive, on ne pourra pas accroître la consommation au niveau souhaitable. L'utilisation des sous-produits du traitement du poisson, de ses écailles et de ses déchets, pourrait réduire le prix de ses parties consommables. Le problème du prix est important à l'égard d'une augmentation de la consommation du poisson, étant donné que la plupart des consommateurs qui apprécient le poisson et voudraient en consommer sont souvent incapables d'en acheter en quantités suffisantes par suite de son prix.

EL PAPEL DEL PESCADO EN LA NUTRICION HUMANA

Una gran proporción del mundo está desnutrida cuantitativa y cualitativamente. El consumo de calorías por persona por día varía de menos de 2.000 a más de 3,000; el de proteína, de 40 a más de 100 g.; el de proteína animal es en ocasiones de solamente 7 g. por persona por día e, incluso, menos en algunos países. No es de extrañar, por lo tanto, que la desnutrición proteínica sea prevalente en muchos países y que esto afecte especialmente a los niños pequeños y de pecho. En muchos países escasean en la alimentación el calcio y las vitaminas, particularmente la vitamina A y varias del grupo B.

El pescado contiene proteínas de elevado valor biológico, comparable con las del huevo, carne y leche. El contenido de proteína, grasas, minerales y vitaminas varía entre las especies; por ejemplo, el contenido de grasa varía de 6 a 20%. El aceite de pescado tiene una proporción más elevada de ácidos grasos no saturados que la grasa animal. Es también una buena fuente de Ca, P, Fe y varias vitaminas. La conservación y manipulación cuidadosa no influyen mucho en su valor nutritivo.

El consumo de pescado es bajo en muchos países en los que se podría esperar un suministro más abundante. A menos que se empleen métodos tecnológicos para poner a disposición del pueblo pescado y productos pesqueros que no estén deteriorados y que no hayan perdido gran parte de su valor nutritivo, su consumo no puede aumentar al grado que sería de desear. El aprovechamiento de los subproductos de la elaboración del pescado (vísceras y escamas) reduciría el coste de la parte comestible. Esta cuestión del coste reviste importancia con respecto al aumento del consumo de pescado, ya que muchas personas, a las que les gusta el pescado y se beneficiarían consumiéndolo, no pueden adquirirlo en muchas ocasiones en cantiades adecuadas debido al precio.

IT is unfortunate that, in spite of the great advances made in the knowledge of food and nutrition and in its application to raise the level of nutrition, the large majority of the human population is still living on a suboptimal nutritional level in the light of the dietary standards recommended by appropriate international and national bodies (1) (2). This relates both to qualitative and quantitative deficiencies in the diet in large areas of the world. The deficiencies are revealed by the national food balance sheets which give the amounts of food in each category available for consumption in any country from internal production after making allowances for seed and feed requirements, exports and imports, stocks, wastage, etc. This situation has been, by and large, confirmed by data obtained from diet surveys conducted on different groups of the population, though the number of such data in different countries is not very adequate.

The levels of both the production and consumption of food in the world are very uneven. The highest rate of consumption prevailing in a few countries is over 3,100 calories per capita per day, whereas in some others it is below 2,000. The qualitative defect in the diet is, however, even more widespread than the quantitative. While in a few countries protein consumption is as high as 100 g. per capita per day, in many countries in Asia, Africa and South America, most of the calories are derived from cereals and starchy roots and tubers, and a relatively minor proportion from milk, eggs, meat or fish. The proportion of protein, particularly protein of animal origin, in the diet in these countries is, therefore, low. In some countries the amount of protein in the average daily diet is only 43 g. (4), of which a very minor proportion (about 7 g.) is derived from animal sources. Likewise, there is deficiency in regard to calcium, vitamin A and the vitamins of the 'B' group in many countries.

Although frank deficiency diseases like scurvy and rickets are not common today, there is fairly widespread protein malnutrition in many countries. This occurs particularly in children, in the late weaning and post-weaning periods. It may be pointed out that the damage that may be done to the body in early life by malnutrition can hardly be made good later in life by correct or even by abundant feeding. The vulnerable groups of the population (viz., the children and the expectant and nursing mothers) have therefore to be looked after with particular care in regard to their food consumption according to optimum nutrition standards.

It is well to remember that national averages of food consumption are made up of the figures for consumption of the best-fed as well as the worst-fed segments of the population. When these averages are low, it is clear that some parts of the population must be living at a very low nutrition standard indeed. It is, therefore, no wonder that children in such segments of the population are the first to suffer from protein malnutrition and other deficiencies. Even in better fed countries, like those of North America, Europe and Oceania, there are some groups of the population who are not consuming the food they need for optimum nutrition, sometimes for low income reasons and sometimes from lack of knowledge.

It may also be recalled that mere freedom from deficiency diseases would not necessarily mean that one is living at the best possible level of health and efficiency of which one is inherently capable. There is, so to speak, a "no man's land" between freedom from disease and optimum health, which has to be conquered by planned action in regard to food and nutrition.

THE NUTRITIVE VALUE OF FISH AND FISH PRODUCTS

The consumption of fish, wherever available in sufficient quantities, can be expected to help considerably in correcting the state of malnutrition so widely prevalent in the world today. Fish is a highly nutritious food. It is particularly valuable for providing proteins of high quality comparable with those of meat, milk or eggs. This similarity is indicated by biological experiments as well as by direct amino-acid analysis. Figures for the essential (and related) amino-acid composition of these different foodstuffs, as reported (4), are given in Table I.

TABLE I

Figures are given in mg. of amino-acid per g. of nitrogen

	Egg	*Milk*	*Meat*	*Fish*
Arginine	400	230	410	360
Cystine .	130	50	80	70
Histidine .	160	170	200	130
Isoleucine .	360	390	320	320
Leucine .	560	620	490	470
Lysine .	420	490	510	560
Methionine	190	150	150	180
Phenylalanine	330	320	260	230
Threonine .	330	290	280	280
Tryptophan	110	90	80	60
Tyrosine .	270	350	210	190
Valine .	450	440	330	330

These figures are, however, only indicative of the pattern of amino acid composition of different animal proteins. Proteins of different species and varieties of fish differ to some extent in their amino-acid composition, and higher figures both for lysine and tryptophan for certain species have been recorded (5) (6). Results also vary depending on the method employed for amino-acid analysis. Generally, however, fish proteins tend to be higher in lysine and lower in tryptophan content than meat. Thus fish appears to supply a high-class protein comparable with those derived from other animal sources. Biological tests with animals and with human subjects confirm the high value of fish protein (7). Fish proteins have also been found nearly to equal casein in plasma protein-regeneration in depleted rats, and to be better than casein in promoting haemoglobin regeneration (8). However, much more detailed work on the proteins of different species of fish, including shell-fish and other marine animals, usable as food, is called for.

Apart from quality, fish constitutes also quantitatively a good source of protein. The edible portions of fresh-water and estuarine fishes investigated in India contain about 14–25 per cent protein (6). In marine fishes also it varies from 9–26 per cent (6). Thus qualitatively and quantitatively, fish consumption might in a significant measure supplement the low-protein, high-cereal diet consumed in many countries of the world. Fish, including processed fish like fish flour, has been found to improve such diets (9). Cereal proteins are rather low in lysine and methionine, in both of which fish protein is relatively rich. Papers are being presented in this Conference reporting the value of fish flour in supplementing high-cereal diets and also in combating protein malnutrition.

Different species and varieties of fish vary in regard to percentages of protein, fat, mineral matter and vitamins (10). There are varieties of freshwater fish which contain as low as 0·6 per cent fat. Such fish should be useful in cases where a low-fat, high-protein diet is recommended. On the other hand, most fish contain higher proportions of fat. Some of the fatty fish have nearly 20 per cent fat. Fish oil has generally more unsaturated fatty acids than animal fats. Since poly-unsaturated fatty acids are beneficial in keeping down the cholesterol level of blood, fish and fish oils are likely to be particularly useful in this regard. This work has only recently begun and should be actively pursued. In this Conference some papers report the effect of the ingestion of fish and fish oils, both in experimental animals and in human beings.

Fish is also a fairly good source of calcium and phosphorus (4), particularly small fish which are eaten with the bones. It is also a source of iron and of a trace element like copper (4). Fish has also a fair proportion of the B-vitamins (4). In regard to most of these nutrients, fish would appear to be comparable with meat. Reports on the nutritive value of different species of fish in these aspects are, however, rather scanty, and more information in this regard is desirable.

The nutritive value of processed fish and fish-products consumed in different countries of the world has also been reported to be high. Canning and freezing do not appreciably affect the protein value. Salted and sun-dried fish, and often fish meals as commercially produced, have also a high biological value. Smoking or dehydration at temperatures not higher than 110°F., or treatment with cathode rays for sterilization, does not significantly affect the amino-acid composition of fish proteins. Some fermented fishery products and fish pastes as consumed particularly in Asian countries are likewise good sources of valuable protein. The indigenous methods of preserving fish in both a nutritious and palatable form have stood the test of time. But more scientific and detailed work on the effect of the methods of preservation, both traditional and modern, is desirable, considering that millions of consumers have to depend on fish preserved in one way or another.

PRESENT-DAY LOW CONSUMPTION OF FISH

Fish is, therefore, a good food, the consumption of which deserves to be encouraged to promote the level of nutrition in the whole world, and particularly in countries consuming high-cereal and low-protein diets. Analysis of the present-day food consumption tables shows, however, that except in a very few countries like Norway, Chile and Japan, where figures for daily per capita consumption are of the order of 104, 82 and 60 g. respectively, fish and fish-products constitute a relatively minor proportion of the total diet in the world. Even in the aforesaid countries, where per capita consumption is the largest, it provides not more than 2–4 per cent of total calories, 10–17 per cent of total protein and 2–15 per cent of the total fat content of the diet (11). In other countries, even those which have a long sea-board, the consumption of fish is less. In some countries like India, the production of freshwater fish is about one-third of that of marine fish, and consumer preference is quite often for the former. In attempts to increase the supply of fish, therefore, increased production of both marine and freshwater fish should be considered.

Taking an overall view of the problem, it would appear that fish provides a valuable source of protein and of oil containing poly-unsaturated fatty acids. The latter are likely to be beneficial in keeping down the cholesterol level of blood. From published work, the proteins of fish appear to be comparable in biological value and in essential amino-acid composition with those of milk, meat and eggs. It is, however, desirable to carry out more detailed researches on different varieties of fish, including freshwater fish and shell-fish and other edible marine animals, and these should be particularly related to the amino-acid composition and the biological value of the proteins and to the fatty acid constituents of the fish oils. The nutritional effects of these proteins and oils and also of the fish as such, both on experimental animals and on human beings in different physiological and also pathological conditions, have to be studied both more extensively and intensively. The minerals, including trace elements, in fish and in its different organs should also be investigated.

The consumption of fish in the world is low. It should be stepped-up wherever possible, and particularly in countries where a high-cereal, low-protein diet is consumed, because there appears to be a definite supplementary relation of the proteins of fish to those of cereals. They have also been reported to have a definite value in combating protein malnutrition in early childhood. Fish is, however, a highly perishable material. It undergoes autolytic, micro-biological and chemical decomposition quite easily. The consumption of fish oils, which had deteriorated because of oxidation, has been reported to produce injurious results on animals. Since most countries consuming a low-protein diet are located in tropical and sub-tropical regions of the world, the consumption of fish in these areas can therefore be stepped-up only if the fish is properly preserved. Apart from the use of ice, which can preserve fish only for very short periods, the methods used in these different countries have been to salt fish, dry it, or prepare fermented products (pastes and sauces) out of it. Other methods like smoking and canning, which are not yet extensively used in these countries, may also be developed. Refrigeration is at present developing, but it is relatively costly both for preservation and for distribution. The development of dehydration, carried out under controlled conditions, to produce an edible fish flour of good quality, should be an important line of advance in future. For certain purposes the fish flour has to be deodorized completely; but some consumers prefer a fish flour with a slight flavour.

Unless technological methods are employed for making fish and fish products available to the people without deterioration, and without considerable loss of its nutritive value, its consumption cannot be increased to the extent which may be desired. The utilization of the by-products of fish processing, its scales and offal, would reduce the cost of the edible portion of the fish. This cost question is important in regard to the increased consumption of fish, since most consumers who like fish and who would benefit by its consumption are quite often unable to buy fish in adequate quantities because of the price.

We trust that this Conference, as the first international scientific conference of its kind, will provide pointers to future progress in regard to the scientific and technological aspects of fish and fish products, and will thus make a contribution to the raising of the nutritional standard of large segments of the human population in the immediate years ahead.

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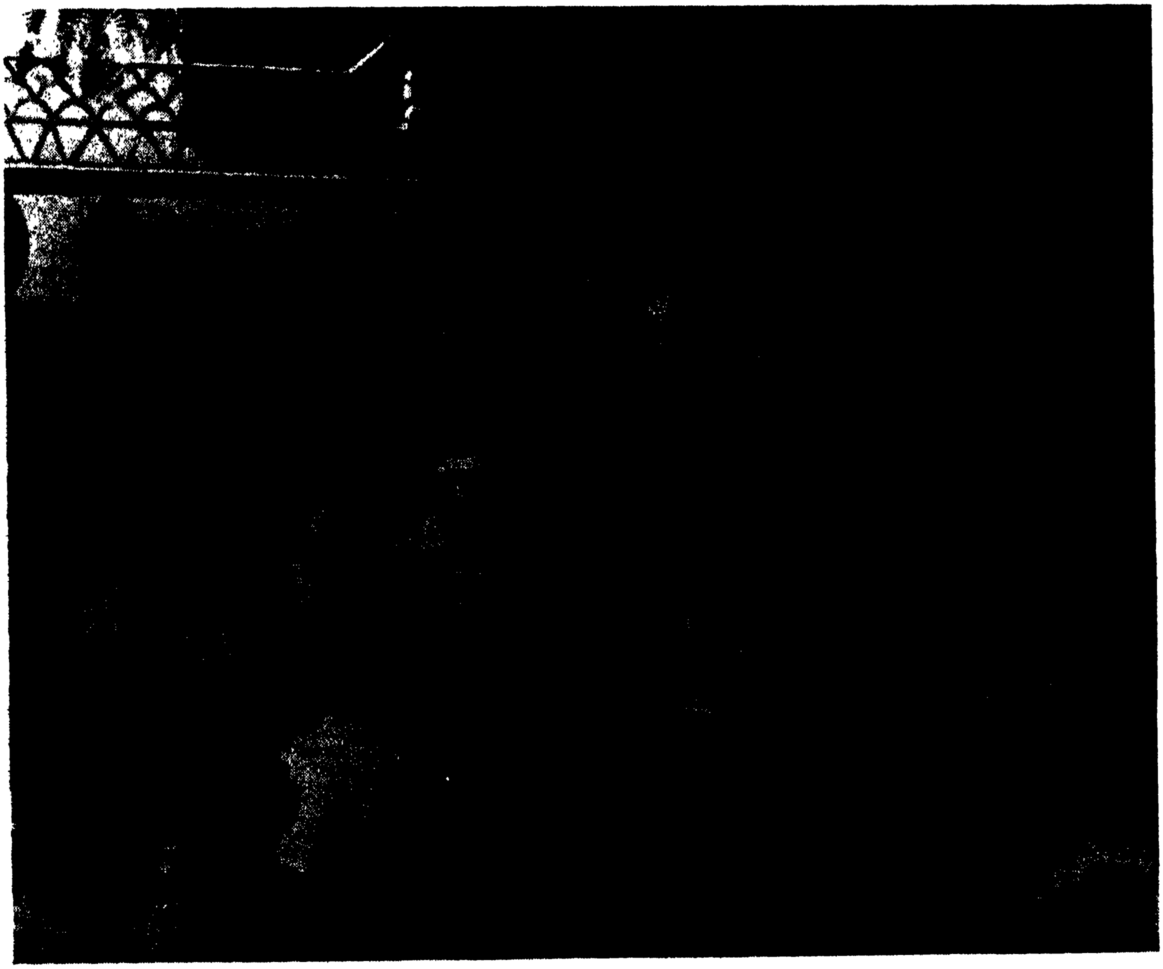

The importance of fish in human nutrition and the interest taken in it is revealed in this picture of a Mexican scene of a fishery food demonstration. This resulted from the visit of FAO's fish marketing expert, John Fridthjof. Demonstrations of cooking fish organized by the Social Security Administration were given in public. The medical truck is accompanied by another containing a kitchen from which come samples of fishery dishes.

THE ROLE OF FISH IN ANIMAL FEEDING

by

G. F. COMBS

An increase in the production of animal feed products can do much to improve the nutritional status of man in many parts of the world. Foods of animal origin, including fish, have exceedingly high quality protein and also are relatively high in many protective nutrients.

Properly processed fish meals are excellent protein supplements for animals, and supply unusually high amounts of amino acids, lysine and methionine, most likely to be limiting in rations for poultry and swine. Fish products are also rich in phosphorus, calcium, manganese, iodine, vitamin B_{12}, riboflavin, niacin and choline. Fish oils are rich in vitamins A and D. The major rôle of fish meal in animal feeding is through the extension of short supplies of protein by providing critical amounts of supplemental lysine and methionine. Under such conditions, as much as 70 per cent of the critically limiting amino acid in the feed may be retained in the production of animal feed products.

The actual usage of fish products in animal feeds is largely determined by economics, but levels up to 10 per cent fish meal can be satisfactorily used in starting and laying feeds for poultry and feeds for swine up to 150 pound weights. For swine and turkeys during the finishing period the level should be restricted to 2·5–5·0 per cent to avoid the possibility of off-flavours in the meat.

The actual level of fish products used in animal feeds is dependent on several factors including the following:

(1) development of intensive swine and poultry industries with increased use of nutritionally balanced complete feeds;
(2) realistic and competitive pricing of fish meal in relation to other available supplements;
(3) availability of fish meal in amounts adequate to insure constant supply;
(4) uniformity and level of quality;
(5) availability and cost of other protein and amino acid supplements;
(6) extent to which nutritional knowledge is applied in animal production.

Probably the most serious deterrent to the production of animal food products for man is the failure fully to apply present technical and scientific knowledge. This includes the sound application of nutritional information in the formulation of feeds designed for specific purposes. This involves the consideration of all aspects of nutrition, and particularly amino acid adequacy where fish products are concerned. It also requires the implementation of other advances, including better management, disease control, use of improved breeds and proper marketing practices if an efficient animal industry is to be realized.

LE ROLE DU POISSON DANS L'ALIMENTATION ANIMALE

Une augmentation de la production des aliments pour les animaux peut au même temps bien améliorer la condition alimentaire de l'homme dans de nombreuses parties du monde. Les aliments d'origine animale, y compris le poisson, présentent des protéines de très haute qualité et une teneur relativement élevée en beaucoup d'éléments nutritifs protecteurs.

Les farines de poisson convenablement traitées représentent des suppléments protéiques excellents pour les animaux, et fournissent des quantités exceptionnellement élevée d'acides aminés, lysine et méthionine, qui sont sans doute des facteurs limitants dans les rations pour la volaille et les porcs. Les produits du poisson sont également riches en phosphore, calcium, mangénèse, iode, vitamine B_{12}, riboflavine, niacine et choline. Les huiles de poisson sont riches en vitamine A et D. Le rôle principal de la farine de poisson dans l'alimentation animale est de compléter des faibles apports en protéines par des suppléments appropriés de lysine et de méthionine. Dans certaines conditions, jusqu'à 70% de l'acide aminé limitant critique de l'aliment donné à l'animal peut être retrouvé dans les produits qu'on obtient de celui-ci.

L'usage pratique des produits du poisson dans les aliments pour animaux est largement déterminé par des considérations économiques, mais des taux atteignant 10% de farine de poisson peuvent être employés d'une façon satisfaisante pour les petits poulets et les poules couveuses et pour les porcs jusqu'à 150 livres de poids. Pour le porc et pour les dindons, le taux de farine de poisson dans le régime de finition devra être abaissé à 2,5–5,0% pour éviter un arrière-goût possible dans le chair.

Les quantités effectives des produits du poisson utilisés en alimentation animale dèpendent de plusieurs facteurs, dont les suivants:

(1) le développement d'industries d'élevage intensives du porc et de la volaille, avec utilisation accrue d'aliments complets et nutritionnellement équilibrés;
(2) un prix réaliste et compétitif de la farine de poisson à l'égard des autres suppléments existants;
(3) des quantités disponibles suffisantes de farine de poisson pour assurer un approvisionnement constant;
(4) la régularité et le niveau de qualité;
(5) les autres suppléments en protéines et en amino-acides disponibles et leur prix;
(6) la diffusion de la science des aliments dans ses applications à la production animale.

Il est probable que l'obstacle le plus sérieux à la production des produits alimentaires animaux pour l'homme consiste dans le défaut d'une pleine application des connaissances techniques et scientifiques actuelles, et par exemple d'une application profonde des renseignements nutritionnels pour formuler des aliments à des fins spécifiques. Ceci demande que l'on considère tous les aspects de la nutrition, et en particulier la convenance des acides aminés, en ce qui concerne les produits du poisson. Pour qu'une industrie animale efficace soit réalisée, il faut aussi mettre en jeu d'autres progrès, y compris une meilleure organisation, la lutte contre les maladies, l'utilisation de races améliorées et des pratiques commerciales mieux adaptées.

EL PAPEL DEL PESCADO EN LA ALIMENTACION PECUARIA

Un aumento en la fabricación de productos para la alimentación de animales puede contribuir mucho a mejorar el estado nutritivo del hombre en muchas partes del mundo. Los alimentos de origen animal, inclusive el pescado, tienen una proteína de calidad superior y también abundan bastante en ellos muchos elementos nutritivos protectores.

Las harinas de pescado bien fabricadas son excelentes complementos de proteína para los animales, y suministran cantidades extraordinariamente elevadas de aminoácidos, lisina y metionina, que probablemente son los factores limitantes en las raciones para aves y cerdos. En los productos pesqueros también abundan fósforo, calcio, manganeso, yodo, vitamina B_{12}, riboflavina, niacina y colina. Los aceites de pescado son ricos en vitaminas A y D. El principal papel desempeñado por la harina de pescado en la alimentación pecuaria consiste en mejorar un suministro escaso de proteína aportando cantidades críticas de complementos de lisina y metionina. En tales condiciones, hasta el 70% de los aminoácidos limitantes críticos en la alimentación pueden ser recuperados en los productos pecuarios obtenidos.

El empleo de productos pesqueros en las raciones para animales, lo determinan principalmente las consideraciones económicas; pero concentraciones hasta de un 10% de harina de pescado pueden emplearse satisfactoriamente en raciones de iniciación y puesta para aves, y

en alimentos para cerdos hasta de 150 lb. de peso. En el caso de los cerdos y los pavos, la concentración en el período final deberá limitarse a entre 2,5–5,0% para evitar la posibilidad de que su carne adquiera sabor a pescado.

La concentración de productos pesqueros empleados en la alimentación pecuaria depende de varios factores, entre los que están los siguientes:

(1) desarrollo de intensivas industrias avicola y de cerda con el uso creciente de piensos completos equilibrados desde el punto de vista nutritivo;
(2) precios realistas y de concurrencia de la harina de pescado con respecto a otros complementos disponibles;
(3) suministro de harina de pescado en cantidades adecuadas para asegurar una disponibilidad constante;
(4) calidad elevada y uniforme;
(5) disponibilidad y costo de otros complementos de proteínas y aminoácidos;
(6) grado en que los conocimientos de nutrición se aplican en la producción pecuaria.

Es probable que el mayor obstáculo a la fabricación de alimentos de origen animal para el hombre sea que no se aplican a fondo los actuales conocimientos técnicos y científicos. Esto comprende la aplicación acertada de información sobre nutrición en la preparación de piensos destinados a finalidades específicas, lo que lleva anejo el examen de todos los aspectos de la nutrición y en particular la suficiencia de aminoácidos en lo que se refiere a los productos pesqueros. También exige la puesta en práctica de otros adelantos, inclusive una explotación más racional, lucha contra enfermedades, y empleo de razas mejoradas y normas de comercialización adecuadas si se desea lograr una industria pecuaria eficaz.

THE unique value of foods of animal origin in upgrading the nutritional qualities of the diet for man is well recognized. Without exception, milk, eggs, meat and fish proteins have exceedingly high biological value in comparison with most other proteins. These products are also relatively high in many of the vitamins, including thiamine and riboflavin. For this reason animal food products, when properly used in relatively small quantities, can improve vastly the adequacy of the entire diet. This is true both for man and for non-ruminant animals.

In those areas of the world where an average of 80–90 per cent of the energy is derived from cereal grains and other plant products, the occurrence of nutritional diseases such as beri beri, ariboflavinosis, and kwashiorkor, are much more common than in others where the diet contains larger amounts of animal products, including fish. To be sure, it is most economical for man to consume fish products directly in supplementing all vegetable diets rather than to feed these to animals for the production of animal products. In many areas, however, the availability of fish products for humans is limited to the nearby coastal areas, due to the lack of inexpensive acceptable methods of preservation and of distribution inland. In such inland areas, the increased production of animal products is most helpful in improving the adequacy of the total diet, especially for infants, young children, pregnant and/or lactating women and medical patients.

It is most economic, also, for man to consume directly the grain, legume and other products of plant origin, rather than to convert them into animal products. This is especially true for energy, as little more than 20–25 per cent of the calories fed to animals can be recovered in edible animal products consumed by man. Protein recovery is higher, ranging from 40 to 50 per cent in animal products, and retention of the critically important amino acids is even greater. The recovery of methionine in the egg, for example, may be as high as 70 per cent of that previously fed to the hen. Since lysine and the sulfur amino acids are likely to be critically limiting in diets for pigs and poultry as well as for man, the conversion of feedstuffs to animal products of high biological value involves the concentration of those amino acids and other protective nutrients most needed with comparatively little loss. Such products are quite effective as supplements to diets low in these essential amino acids. In this way, animal proteins can effectively extend the value of most available plant proteins.

Other factors, such as the ability to utilize roughages, industrial by-products and "inedible" wastes, with the production of most acceptable, high quality, supplemental foods of animal origin near the site of consumption by humans, are important reasons for the development of more animal agriculture in "underdeveloped" areas of the world. Diets for man can be adequate in amino acids and other protective nutrients without the use of animal products; but such diets are usually less acceptable and frequently no more economical than are mixed diets balanced in nutrients from both vegetable and animal origin. The high concentration of the critical amino acids (sulfur amino acids, lysine, and tryptophan), vitamins and other protective nutrients in animal products is such that relatively small quantities are needed to improve greatly the diet of man. Thus, animal products may supplement foods that could never be used satisfactorily alone. Moreover, such foods, especially milk and eggs, are ideally suited for the feeding of infants and the sick. For these reasons, an increase in animal food production in many areas of the world can aid materially in correcting the widespread undernutrition which now exists.

NUTRITIONAL CONTRIBUTIONS OF FISH PRODUCTS

Just as fish and other animal products are of special value in supplementing the cereals and other vegetable foods consumed by man, fish products are equally important in the feeding of non-ruminant animals. Properly processed fish meals are among the very best sources of high quality protein for animals, and contain relatively high quantities of lysine and methionine. They are also rich in other essential amino acids, and supply important quantities of critical minerals (phosphorus, calcium, manganese, iodine) and vitamins (vitamin B_{12}, niacin and choline). Condensed fish solubles contain exceptionally high levels of vitamin B_{12}, and supply important amounts of niacin, pantothenic acid and riboflavin.

Both fish meal and condensed fish solubles have been reported to supply an "unidentified growth and hatchability" factor(s) of practical importance in rations containing little or no ingredients of animal origin. Despite the multiple nutritional values of fish products, their ability to furnish those essential amino acids which are most likely to be critically limiting in other commonly available proteins largely determines the amount which can be most economically used in the efficient production of animal products.

In the past, fish products have contributed importantly in animal feeding by supplying various vitamins and minerals, not adequately supplied by cereal grains or plant protein supplements. Fish products have been used widely in starting rations for pigs and poultry, and in breeder rations for poultry because of their "unidentified factor" activity. With the rapid unfolding of nutritional discoveries of recent years, followed by the equally vigorous rôle of the manufacturing chemist, nearly all of the vitamins and minerals, critical for animal feeding, are now readily and economically available. This is true for the amino acid methionine (or the hydroxy analogue), and lysine also is available now as a supplement to animal feeds.

In addition to the increased availability of most of these critically limiting nutrients, including vitamin B_{12}, riboflavin, methionine and phosphorus, other advances have revealed the importance of zinc, selenium, molybdenum, potassium, nutrient balance, ration potency and improved amino acid adequacy in performance of animals fed various rations. These developments have resulted in a marked improvement in rations for poultry and swine. At the present time, the "unexplained responses" in growth and hatchability, as a result of using "unidentified factor supplements", have been greatly reduced or even eliminated.

Even now, fish products usually improve the growth rate of young chickens and turkeys to a slight extent when used at levels of 2·5 or more per cent in practical feeds. Such minimal usage is justified at present on the basis of unidentified factors; but further advances in nutrition can be expected to lead to the identification and manufacture of the responsible nutrient(s) in the future.

Accordingly, the long-term use of fish products for animal feeding must be justified primarily on the basis of the value of their known nutritional contribution in relation to cost and availability from other sources. The value as sources of critically important vitamins and minerals in animal-feeds can be readily determined in terms of the cost of these nutrients from other sources. Of major importance, however, is the ability of fish products to supply those amino acids which are most likely to be critically limiting in other available proteins.

Extending critically short protein supplies

Not only is protein in short supply in many parts of the world, but the proteins of cereal grains and most other plant protein concentrates fail to supply fully the amino acid needs of poultry and swine. For poultry, the sulfur amino acids (methionine and cystine) or lysine are frequently limiting in plant protein mixtures. For swine, lysine and tryptophan more commonly may be critical. In general, cereal grains are low in all three of these amino acids. Soybean oil meal, widely used in animal

TABLE I

Critical amino acid content of proteins from various sources

	Expressed as per cent of protein[1]				
Ingredient	*Methionine*	*Methionine + cystine*	*Lysine*	*Tryptophane*	*Glycine*
Animal Protein Supplements					
Herring fish meal	2·8	3·7	9·0	1·3	7·5
Sardine fish meal	3·0	3·8	9·0	1·3	7·1
Menhaden fish meal	3·0	3·8	9·0	1·3	7·0
Meat scrap	1·3	2·6	6·8	0·7	13·2
Tankage	1·1	1·9	6·0	0·7	?
Plant Protein Supplements					
Soybean meal	1·4	2·9	6·4	1·5	5·3
Cotton seed meal	1·5	3·5	4·2	1·3	5·3
Peanut meal	0·9	2·4	3·6	1·0	5·1
Cocoanut meal	1·1	?	3·2	0·9	?
Corn gluten meal	2·4	3·8	1·7	0·5	3·5
Sunflower seed meal	3·4	5·0	4·0	1·3	6·0
Sesame meal	3·1	4·4	2·9	1·7	9·3
Cereal Grains					
Corn	2·0	3·7	2·2	1·0	3·3
Oats	1·5	3·3	4·1	1·3	4·2
Milo	1·6	3·1	3·0	1·2	?
Wheat	1·3	3·0	3·1	1·2	?
Barley	1·4	3·1	3·3	1·2	?

[1] Based on data by Almquist.

TABLE II

Comparable rations for laying hens, illustrating the rôle of fish meal and DL-methionine in extending plant proteins

Amino acid source	*Layer rations Per cent Composition*				
Corn	66	70·5	75	78·2	
Dhy. alfalfa meal, 17%	2·5	2·5	2·5	2·5	
Soybean meal, 50%	23·3	18·8	14·3	7	
Fish meal, 60%	—	—	—	5	
DL-methionine	—	0·03	0·06	0·02	
Nutrient Content					
Crude protein, %	17·6	15·6	13·6	13·3	
Met. cal./lb.	1343	1365	1386	1416	
	G. per Therm Met. Energy				*Calc.*[1] *Req.*
Methionine	0·96	0·96	0·96	0·96	0·96
Methionine + cystine	1·84	1·78	1·72	1·73	1·64
Lysine	3·04	2·54	2·04	2·16	2·02
Tryptophan	0·84	0·72	0·59	0·54	0·47
Isoleucine	2·82	2·48	2·13	2·03	2·02
Crude protein	61	52·8	44·5	42·5	—

[1] Based on author's method. Underlined values are considered just adequate for 80 per cent production of 2-ounce eggs by 4-pound hens in the fall.

feeding, is a very good source of lysine and tryptophan, but is low in sulfur amino acids. Sesame meal and sunflower seed meal are rich in sulfur amino acids and tryptophan, but are low in lysine. Meat scraps and tankage are good sources of lysine, but may be low in tryptophan. Fish protein, on the other hand, is an excellent source of all three of these amino acids, particularly methionine and lysine. A comparison of the content of critically limiting amino acids in proteins from plant and animal origin is given in Table I. These values are expressed as per cent of the protein and may be compared directly.

Accordingly, the problem of meeting the amino acid needs of poultry and pigs involves more than merely supplying a recommended level of protein in their ration. Intelligent use of the proper combinations of proteins can do much to extend the effectiveness of the presently available protein supplies throughout the world, for both animals and man. Since fish protein contains unusually good levels of methionine and lysine, fish products are particularly useful in supplementing cereal grain and other plant protein.

Not only is fish protein ideally suited to extend the amino acid adequacy of other available protein supplies; but whereas the hope for rapid increases in the supply of other animal projects is not great, it appears that considerable increases in the production of fish protein for animal feeding can be expected.

TABLE III

Rôle of fish meal and methionine hydroxy analogue in extending plant protein in broiler starting rations

Amino acid source	*Broiler starting rations Per cent Composition*				
Corn	35·3	60·9	64	67·3	
Dhy. alfalfa meal, 20%	1·25	1	1	1	
Corn gluten meal, 60%	—	2	2	2	
Cond. fish sol.	2·5	—	—	—	
Soybean meal, 50%	46·5	30	21·5	13·3	
Fish meal, 60%	—	—	6	12	
Methionine hydroxy analogue	—	0·075	0·038	—	
Nutrient Content					
Crude protein, %	27·6	21·9	21·6	21·3	
Met. cal./lb.	1450	1429	1465	1501	
	G. per Therm Met. Energy				*Est.*[1] *req.*
Methionine	1·27	1·34	1·37	1·40	1·30
Methionine + cystine	2·54	2·42	2·45	2·48	2·40
Lysine	5·00	3·53	3·67	3·81	3·40
Tryptophan	1·21	0·92	0·86	0·81	0·70
Glycine	4·40	3·40	3·40	3·40	3·40
Crude protein	86	70	67	64	

[1] Author's estimate.

Another way to extend the effectiveness of plant proteins in animal feeding is through the use of amino acid supplements *per se*. Fortunately, DL-methionine and its hydroxy analogue are available to supplement directly feeds critically limiting in methionine. This is commonly done in poultry containing soybean meal as the major source of supplemental protein. Lysine also is available now for addition, and future reductions in price may render it economical for widespread use, especially in pig-feeds. In rations, however, where both methionine and lysine are limiting, the cost of the amino acid supplements must be considerably reduced in order to compete economically with good quality fish protein as a means of supplying these essential amino acids.

Tables II and III show the amino acid sources in rations for laying hens and starting broilers, respectively. These contain corn, soybean meal and fish meal as primary protein sources, and have been fed at the University of Maryland without differences in performance. These rations vary widely in total protein, but all are considered adequate in essential amino acids, a few of which are given. Such formulae illustrate clearly the potential rôles of fish meal and methionine in extending greatly the value of vegetable proteins. Actually, corn and soybean meal protein is low in sulfur amino acids only, while most other plant proteins available for feeding are also quite low in lysine, an amino acid abundantly provided by fish protein. Unquestionably, fish protein occupies a unique position in its ability to supplement and extend proteins of plant origins and greatly improve the production of animal products available for man throughout the world.

The importance of balance interaction between fish and other proteins in studies with chicks has been reported by Laksesvela (4). Herring solubles were found to improve herring meal; but introduction of certain cereals and peanut meal quickly converted the beneficial effect of the solubles into a negative one. Further replacement of soybean meal protein for peanut protein reversed this situation again. In this work amino acid supplementation revealed that the differences could be explained entirely on the basis of amino acid levels and balance. This report stresses the practical importance of skilful combination of different protein sources.

Extent of use of fish products

The use of fish meal has been greatest in those European countries, and in the United States, where animal industry is more intensified. Over the years, higher levels of fish products have been used in animal feeds in the European countries than in the United States, largely for economic reasons. Processed soybean protein has been available in the United States in recent years and has become a dominant protein source for pigs and poultry. Soybean protein and supplemental DL-methionine or hydroxy analogue made possible the formulation of satisfactory rations with little or no animal protein supplements. In most starting and breeder feeds for poultry, minimal levels of 2·5 per cent fish meal or 1 per cent condensed fish solubles are still commonly used as a means of supplying "unidentified factors". Little fish meal has been used in swine rations in the United States, although condensed fish solubles have been used to some extent. Recently, considerably more fish meal is being used for poultry and pigs, due to more favourable prices in relation to other high protein feedstuffs. In Europe, pig and poultry feeds may contain as much as 10 per cent fish meal.

The actual level of fish products used in animal feeds is dependent on several factors including the following:

(1) development of intensive swine and poultry industries with increased use of nutritionally balanced complete feeds;
(2) realistic and competitive pricing of fish meal in relation to other available supplements;
(3) availability of fish meal in amounts adequate to insure constant supply;
(4) uniformity and level of quality;
(5) availability and cost of other protein and amino acid supplements; and
(6) extent to which nutritional knowledge is applied in animal production.

The maximum levels of fish products which can be tolerated by animals are expressed best in terms of amount of fish oil they supply in the total ration. The level of oil which can be tolerated without imparting off-flavours to the flesh of poultry and pigs appears to vary with the type of fish and processing method. In a study conducted at Storrs, Connecticut (Carlson *et al.*, unpublished), broiler chickens reared to 8 weeks on diets containing as little as 1 per cent crude Menhaden oil and 5 per cent Menhaden fish meal were rated unfavourable because of fishy flavours by a taste-test panel. Broilers fed rations containing 0·5 per cent crude Menhaden oil were not different from those fed a control diet. No complaints because of fishy flavours were reported for meat of broilers fed the diets containing added crude ocean perch oil at either 1 or 2 per cent levels.

Reports of fish flavoured eggs are much more difficult to interpret, although one recent study indicated that a ration containing as little as 9 per cent of a commercial herring fish meal produced eggs with fishy odours in from 11 to 15 per cent of the eggs. By changing the feed to one containing no fish meal, the occurrence of fishy flavoured eggs disappeared. Other reports exist where considerably higher levels have failed to cause fish flavoured eggs. Lea, Parr and Carpenter (6) detected no tainted meat or eggs of hens fed fresh or oxidized herring meal for 2 months at a level of 8 per cent in their diet. It is considered desirable, generally, to restrict the level of fish products in the diet of poultry to one which does not supply more than 1 per cent total fish oil in the ration.

Approximately the same criteria appears to be satisfactory for pigs, since levels of about 8–10 per cent Menhaden fish meal have been used with no noticeable adverse effects by the Bureau of Commercial Fisheries, United States Department of the Interior, College Park, Maryland.

Excessive levels of raw fish also may be detrimental due to their content of the enzyme, thiaminase, which destroys thiamine. Although not all fish contain thiaminase, this can be a problem particularly in the feeding of mink and other fur-bearing animals where raw fish is used. Because of this, it is not considered desirable to use more than 25 per cent raw fish in the diet of mink.

The maximum level of fish meal which might be used can be stated as approximately 10 per cent for poultry feeds and 8–10 per cent in feeds for pigs up to 150 pounds. After this, pigs do not require such a high level of supplemental protein. Levels of 2·5–5·0 per cent might be considered maximal from the standpoint of off-flavours during the latter part of the growing period. For turkeys during the finishing period, it is advisable also to restrict the level of fish meal from 2·5 to 5 per cent of the ration, in order to avoid the problem of fish flavours in the meat.

The actual level of good quality fish products, which should be used in the formulation of good nutritionally sound feeds for animals, should be entirely a matter of economics until the maximal level is reached and would be expected to differ greatly. Though this is easily said, it is somewhat difficult to estimate the relative value for fish meal as a source of nutrients in relation to other competing sources without rather detailed calculations. It is totally wrong, for example, to divide the cost of fish meal by its protein content, and so arrive at a cost per pound of protein, since fish meal supplies many other economically important nutrients as well. Furthermore, protein varies markedly in amino acid make-up, as has been pointed out, and the supplemental feeding value of a particular mixture of amino acids such as that found in fish meal may be influenced greatly by the amino acid make-up of the remainder of the protein in the total ration. Furthermore, the supplemental value of fish meal changes with the level used in a particular feed. In broiler feeds, for example, the "unidentified factor activity" is of economic value only at minimal levels of usage. From 2·5 per cent to approximately 8 per cent in corn soybean meal type rations, its value is primarily one of supplying critically limiting amino acids which extend the effectiveness of the other available proteins in the feed. Above this level, the high quality protein of fish meal is of much less economic or nutritional value, as it is no longer required to improve the amino acid balance. This also is influenced by the protein level and quality of the initial ration. Hence, the manner in which fish meal is used can greatly influence its value and the level most economical for use.

Proper use of linear programming procedures for formulation of animal feeds provides a means for the feed manufacturer to appraise the relative worth of various ingredients as sources of critical nutrients. As this practice becomes more prevalent, it will be easier to determine the proper levels of each ingredient to use for most economical formulation of animal feeds. Even this procedure, however, can be misleading, unless proper information is used in the programming, provided that arbitrary decisions are not made which will modify wrongly or prevent the best solution.

Where machine calculations are used to determine the best combination of feedstuffs to meet fully the nutritional needs of animals at the lowest cost, every effort should be made to state requirements properly. For example, if one requests the machine to formulate a broiler feed with a minimum of 24 per cent protein and 1,430 calories of metabolizable energy per pound, when 22 per cent protein can be adequate provided it is of high quality, the arbitrary protein level causes the machine to select a ration with the higher level. This might or might not be the most economical feed. If this arbitrary restriction is replaced by requirements for amino acid content, the calculation will be influenced more by the amino acid make-up of various available protein-rich ingredients.

Another approach as a means of comparing the relative value of different feed ingredients, based on their nutrition contribution, is that of calculating the Partial Nutritional Worth (3). This method is designed to calculate the relative values of feed ingredients for use in starting feeds for poultry and, in addition to energy and protein values, the levels of vitamin A, riboflavin, pantothenic acid, choline, niacin, vitamin B_{12}, calcium and phosphorus are considered of critical importance. This procedure involves the calculation of the relative partial worth of each ingredient based on its contents of these critical nutrients, energy and protein. Energy and protein values are determined by using reference ingredients (such as corn and soybean meal) with two equations and two unknowns. With this method, the Partial Nutritional Worth of fish meal or any other ingredient may be calculated for a given market situation at a given location and compared with its actual market price. Certain factors cannot be evaluated directly by this method, such as differences in protein quality, unidentified growth factor activity, effect on potency of the feed, toxic substances, etc. Nevertheless, special calculations may be performed as required to consider the additional values of any particular ingredient, including special amino acid contributions.

Certainly the availability of other protein supplements can be expected to influence the use of fish proteins for animal production. Combinations such as soybean meal plus DL-methionine or its hydroxy analogue can largely eliminate the need for fish products in animal feeds in certain areas, if economics so dictate. However, peanut meal or cotton-seed meal can be used satisfactorily in feeds in only limited amounts and in combination with other feedstuffs. The use of these, therefore may increase the need for fish meal, since these proteins are deficient in both lysine and methionine. Animal proteins, in the form of tankage and meat scraps, are somewhat limited in supply and are considerably lower in methionine than is fish protein. With proper use of fish proteins, it should be possible to extend considerably the present limited supply of proteins for animal feeding.

Our challenge—The proper application of knowledge

As improvements in animal production are made, more animals will be fed complete rations designed to be more efficient. Such an increased use of balanced feeds would greatly extend the present limited feed supply for animals by preventing waste of feedstuffs through misuse in unbalanced feeds consumed by animals maintained under poor conditions.

Even in the formulation of commercial feeds, there appears to be considerable room for improvement from the standpoint of assuring efficient and economical production. Meeting the requirements for most vitamins and minerals is seldom difficult to accomplish, but still is not always done. Special vitamin and mineral supplements are usually obtainable at relatively low cost, which permits marked flexibility in formulation. As far as protein and energy levels are concerned, however, the problem is frequently more difficult. Most of the cost of feeds is due to the cost of energy and protein. Furthermore, concentrated sources of feed energy for poultry and pigs are in short supply in many areas of the world. Where low fiber, high energy grains such as corn and wheat are not readily available for the use in feeds, it is frequently difficult to formulate rations sufficiently high in energy content to support the most rapid growth of chicken broilers or starting turkeys, unless feeds are pelleted.

Protein supplies for animal feeding also are critical in many countries. Furthermore, the amino acid quality of much of the available protein is poor for the feeding of non-ruminant animals. Far too much concern is given to protein level in feeds and too little to the amino acid content. Actually, the amino acid levels should be considered in relation to energy content and feed intake in the formulation of rations for non-ruminant animals. The energy needs of animals vary with several factors which largely determine feed consumption; hence, these factors affect feed intake and consequently the levels of other nutrients required in terms of per cent of the ration.

Better information is rapidly becoming available which permits more careful formulation of rations designed to be adequate in amino acids, but still not wasteful of protein. In some countries, protein is relatively cheap, even at the present time, so that less concern is given to the most efficient use of it. However, with better distribution and use of feed ingredients, wasteful use of protein resources could be avoided, and the present scarce supplies could be extended greatly. The proper uses of fish meal protein and amino acid supplements are key factors in achieving such improvement.

Not only should more attention be given to application of that which is already known, but scientists should continue to extend this information in many areas. For example, considerable improvement can be expected in expressing amino acid requirements of pigs and poultry in relation to direct physiological functions instead of as a percentage of their feed. In poultry, for example, the amino acid needs vary with maintenance needs, growth rate, egg production and body composition. Furthermore, the estimating of energy needs and feed intake as functions of temperature, activity, rate of growth, level of production, egg size, body composition and other factors requires more study. Nevertheless, the sound application of the vast amount of knowledge now available can greatly improve the use of present feedstuffs for animal feeding.

Another challenge to meet in relation to the use of fish products in animal feeding is the need for consistently high quality products. Even though fish meals are of good quality generally, considerable variation does exist from time to time. It is obvious that feed ingredients must be dependable sources of the critical nutrients for which they are primarily used, or their usefulness will be greatly curtailed. In this regard, not only high quality but uniformity of quality is important. Without better quality control and uniform production of high quality fish products, the degree to which the feed manufacturer can depend upon these products, as sources of lysine and methionine, will be impaired. Improved uniformity of feedstuffs is essential to most efficient formulation and use of available ingredients.

The causes of the differences in quality of various fish meals is not completely known, but poor quality fish meals generally show lower protein and fat digestibility. The protein digestibility may range from 60 to 90 per cent with most fish meals of good quality averaging 80 per cent or better. The digestibility of fat is also impaired, and perhaps may account for the impaired digestibility of protein and the difference in availability of amino acids (5). The addition of antioxidants delays these changes and has proved helpful in maintaining good quality fish meal over longer periods of time. In general, meals prepared from non-oily fish are consistently better in quality than meals prepared from oily fish, although these non-oily fish meals can be of poor quality and oily fish meals can be of high quality. Fish meal prepared from different species containing oils of different characteristics, therefore, would be expected to vary when lipid considerations are important. Certainly, more research is needed to determine the actual causes of differences in quality.

The importance of fish oil as a primary source of vitamins A and D both for man and for other animals also should be recognized. In the past, of course, fish meal was a by-product of fish oil production. Recently two other uses of fish oils have been suggested and deserve considerable attention. The first is its possible value as an unsaturated fat in reducing blood cholesterol level. The second involves the use of fish oil as a means of supplying unsaturated fatty acids to young calves and beef animals as a means of improving growth rate and protein retention.

Probably the greatest challenge in this area of food production is in the education of people. Only through basic education, and the extension of information already available in the practical production of livestock and poultry throughout the world, can rapid improvements in the nutritional health of man be expected. This challenge should affect many groups such as FAO in the implementation of their programs. These should include the training of specialists in efficient animal production throughout the world.

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DISCUSSION

DR. C. L. CUTTING (U.K.): In discussing protein, we really mean amino acids. I do not feel we can justify feeding fish to animals at all. In view of FAO responsibility, it is regrettable that 95 per cent of fish meal is used by the U.S. and other countries where malnutrition is least. In many cases, poor distribution limits the availability of fishery products to coastal areas. To effectively utilize fish from coastal areas, preservation techniques must be improved. I challenge the statement made by Dr. Combs that lack of preservation methods is the hampering factor.

DR. G. F. COMBS (U.S.A.) agreed with Dr. Cutting, and stated that, in areas where production of fish is limited and transportation is poor, use of animal products is necessary to supply suitable proteins.

DR. GEORG BORGSTRÖM (U.S.A.) strongly endorsed the comments made by Dr. Cutting, but amplified a few points. The tremendous gap between have and have-not nations was not yet fully recognized. Fish is approximately 12 per cent of total animal protein, but nourishes far more than this percentage of world population. To more than one billion people, it constitutes the chief source of animal protein. Milk and meat show the reverse pattern, and feed less millions than their percentage of the total would indicate. Fish is the protein for the poor, nationally and globally. The tremendous gap that now exists is best illustrated by the case of the U.S. If the entire world catch were fed to U.S., this would not provide more protein than U.S. now is getting through meat. It is most noteworthy that the largest producers of fish meal are the protein deficient areas such as tropical Africa (Angola, Congo, etc.). Some Latin American countries are almost equally deficient (Peru), whereas the consumers, Western Europe and U.S., are the best fed countries. Many people in the western world indirectly depend on the sea for their poultry, meat, milk, etc. One-third of the U.S. broiler production can be attributed to the sea. He was convinced that 400 million people cannot continue to get the overwhelming part of the world's animal protein, while 2·5 billion are neglected and even deprived of this essential nutrient. This is our challenge. He knew of no other area of the food scene today where a marginal effort would have more substantial effect than just here. We have the methods, such as dried fish and fish flour. In future, the rich countries cannot expect to continue to use fish resources directly for animal feeding, but must be satisfied with refined waste products of the fish industry. Politically and economically, the present situation is absurd and will not persist.

PROF. H. R. BIRD (U.S.A.): Several references to fish flour presage the eventual upgrading of some of the fish meal now used for animal feeding into a product suitable for human food. Animal feeding is a very opportunistic operation which makes use of whatever products and byproducts are available at suitable prices. Dr. Combs' paper indicated the alternatives available if the supply of fish meal for animal feed is decreased. We have been through this before with byproducts of the dairy and meat-packing industries which have been upgraded for human food use.

DR. C. L. CUTTING (U.K.): Is any use of fish in animal feeding justified?

DR. B. C. GUHA (India): If offals and residues are processed for animal feed, this should reduce the cost of that part of the fish used as human food. Experience with dairy and meat-packing industries indicates that there is always some residue left to be processed for animal food.

MISS RUTH M. LEVERTON (U.S.A.) wished to add to Dr. Combs' statement that the use of animal products to help meet protein needs is justifiable. It is possible, however, that we could meet amino acid requirements and still have serious malnutrition. Food sources of good quality protein are also sources of essential nutrients other than amino acids—the same nutrients that are in short supply in diets of many population groups in the world. We are justified in emphasizing ways of meeting nutritional needs with foods wherever possible rather than only from nutrients in isolated purified chemical form.

PROF. HERNAN CABALLERO D. (Chile): We have a wealth of fishery resources off the coast of Chile and a fishing industry to make it available to our people. Chilean people use considerable amounts of fish, particularly in the fresh condition. I agree with Dr. Combs in believing that it is extremely important to study and improve diets for animal feeding. Present diets often are of poor quality and not always fed to animals of good quality. Fluctuations in price and in the supply should be controlled. We should intensify the use of fish meal and flour. In deciding whether to use fish for human consumption or for animal feeding, it would be best to follow both paths.

DR. A. BACIGALUPO (Peru): Our fishing industry in Peru is young. It seems strange that Peru exports meal while her people are underfed. But now that the industry is well established, we must promote further fish consumption within our borders. Our educational and research efforts must be increased to do this. We must improve our channels of distribution and our support of research. In the university we are studying the use of fish in animal nutrition.

DR. O. R. BRAEKKAN (Norway): We must remember that much of the vegetable protein is available to us because cattle diets are supplemented by fish meal. Thus the loss of energy and nutritive value is not as great as we assume.

DR. A. J. VAN VEEN (FAO): Every nutritionist should be in favour of encouraging humans to eat fish protein. However, we must recognize that economic conditions in some countries limit the application of preservation methods. Even minimum processing may make fish too expensive for some people. But fish flour offers considerable promise as an inexpensive protein supplement. This is a new and unknown food, however, and people must eat it because they like it. This will take time and education.

Dr. M. M. Abdel Kader (U.A.R.): What percentage of the world population likes to eat fish?

Dr. R. Kreuzer (FAO): It is not possible to generalize on the proportion of people that like to eat fish. It varies from 100 per cent for Eskimos to almost nothing in some countries, and from 100 per cent in coastal areas to nothing in the interior of the same country.

Dr. G. M. Dreosti (South Africa): The two vital problems of economic and food habits are beyond the scope of fishery technologists and nutritionists. If the underprivileged do not have enough money to buy even fish meal, then fish meal production will not help them. The problem is for the economist. The problem of incorporation of fish products such as fish meal in the diets of these people is again for the dietician, not the nutritionist. So two vital problems lie outside the orbit of our work here.

Mr. Hugo Loredo (Mexico): Fresh fish can be divided into three classes—luxury, medium, and cheap. The last category supplies the immediate needs of most of the people. But industrialists do not have too much interest in altruistic motives. Possibly the governments should undertake such activities. In Mexico, the Government operates a plant that processes dried fish at 8 cents per 250 grams.

Prof. S. Konosu (Japan) disagreed with Dr. Guha and stated that he will give his opinions in Part III.

Animal feeding has improved greatly in recent years by the production of fish meal in large quantities. A leader in the field of heavy production was South Africa, closely followed and surpassed in recent years by Peru. Picture shows elevator installed at a West African port carrying fish to the factory. While the southern hemisphere produces the greatest quantity of fish meal, it is mostly exported to the northern hemisphere for incorporation in foods for stock and poultry. *Photo: Courtesy Atlantic Ocean Fisheries.*

PART II

CHEMICAL COMPONENTS OF FISH AND THEIR CHANGES UNDER TREATMENT

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Section 1: PROTEINS AND GENERAL COMPOSITION

PROXIMATE COMPOSITION OF FISH

by

MAURICE E. STANSBY

(1) Efforts over the past century to establish the proximate composition of fish have been only partially successful, as many gaps in our knowledge still exist.
(2) Large variations occur in proximate composition, both from species to species and also from fish to fish of the same species. In addition, large variations occur in composition of different parts of the fish.
(3) The protein content of fish, although averaging about 19 per cent, may vary from 6 to 28 per cent. Oil content may vary from 0·2 to 64 per cent, ash from 0·4 to 1·5 per cent, and moisture from 28 to 90 per cent.
(4) A classification into five categories with respect to oil and protein contents of fish is proposed. Most species fall into the category of low oil and high protein content.
(5) The cause of variation in the proximate composition of fish, often ascribed to such factors as geographical area or season, actually relates primarily to the feed ingested, to the metabolic rate, and to the mobility of the fish.
(6) The approximate content of certain vitamins and minerals in fish has been briefly discussed.
(7) Need for proximate composition of fish is currently greater than in the past, because of the trend for heart specialists to recommend diets requiring either low fat or a minimum of saturated fat, both of which can be obtained by using generous proportions of fish in the diet. Other needs for proximate composition data occur in various other fields of fishery technology, such as for calculating yield in the processing of various products.

COMPOSITION IMMEDIATE DU POISSON

(1) Les efforts réalisés durant le siècle écoulé pour établir la composition immédiate du poisson n'ont été que partiellement couronnés de succès, car il existe encore de nombreuses lacunes dans nos connaissances.
(2) De larges variations apparaissent dans la composition immédiate non seulement d'une espèce à l'autre, mais encore d'un poisson à l'autre à l'intérieur d'une même espèce. De plus, il existe de grandes variations dans la composition entre les différentes parties du poisson.
(3) La teneur en protéines du poisson, tout en présentant une valeur moyenne de 19 %, peut varier de 6 à 28%. La teneur en huile peut varier de 0,2 à 64%, les cendres de 0,4 à 1,5%, et la teneur en eau de 28 à 90%.
(4) On propose une classification en 5 catégories en fonction des teneurs en protéine et en huile du poisson. La plupart des espèces se placent dans la catégorie à teneur faible en huile et haute en protéine.
(5) Les causes de variation dans la composition immédiate du poisson, souvent attribuées à des facteurs tels que la région géographique ou la saison, le sont actuellement et principalement à la nourriture ingérée, au taux du métabolisme et à la mobilité du poisson.
(6) On étudie brièvement la teneur immédiate en certaines vitamines et en minéraux dans le poisson.
(7) Le besoin de disposer de la composition immédiate du poisson est plus important que par le passé, par suite de la tendance des cardiologues à recommander des régimes qui exigent soit peu de graisses, soit un minimum de graisses saturées, et qui peuvent être obtenues, les unes et les autres, avec une large utilisation de poisson dans le régime. Des données sur la composition immédiate du poisson sont aussi nécessaires dans des secteurs divers de l'industrie du poisson, comme par exemple pour les calculs de rendement dans le traitement de divers produits.

COMPOSICION APROXIMADA DEL PESCADO

(1) Los esfuerzos realizados durante un siglo para establecer la composición aproximada del pescado, solamente se han visto parcialmente coronados el éxito, puesto que aún existen muchas lagunas en nuestros conocimientos.
(2) Existen grandes variaciones en la composición aproximada, no sólo de una especie a otra, sino también de un pez a otro de la misma especie. Además, también existen grandes variaciones en la composición de las diversas partes del pescado.
(3) El contenido de proteína del pescado, aunque con un valor medio de 19%, puede variar de 6 a 28%; el de aceite puede variar de 0,2 a 64%; el de ceniza, de 0,4 a 1,5%; y el de agua, de 28 a 90%.
(4) Se propone una clasificación en 5 categorías, en función del contenido de aceite y proteína del pescado. La mayor parte de las especies están comprendidas en la categoría de bajo contenido de aceite y alto de proteína.
(5) Las causas de las variaciones en la composición aproximada del pescado, aunque atribuidas con frecuencia a factores como zona geográfica o estación, se relacionan real y principalmente con el alimento ingerido, metabolismo, y movilidad del pez.
(6) El contenido aproximado de ciertas vitaminas y minerales en el pescado se examinan brevemente.
(7) La necesidad de disponer de una composición aproximada del pescado es actualmente mayor que en el pasado, debido a la tendencia de los cardiólogos a recomendar dietas que exigen pocas grasas o un mínimo de grasas saturadas, condiciones ambas que pueden obtenerse empleando generosas proporciones de pescado en la alimentación. Los datos sobre la composición aproximada son también necesarios en otros sectores de la tecnología pesquera, por ejemplo, para calcular el rendimiento en la elaboración de diversos productos.

ABOUT 30 years ago, when I was starting my career in the old U.S. Bureau of Commercial Fisheries laboratory at Gloucester, I found a situation which at that time surprised me very much. Whereas all the nutrition and composition tables showing data for fish indicated that the common mackerel contained only 6 per cent oil in the edible flesh, analysis of samples of this species from the local commercial catch indicated that the average oil content was about two to three times this amount.

Even 30 years ago, proximate composition was considered to be such an elementary sort of thing that scientists felt they ought to spend their time on something requiring more skill. Surely, so the argument went, proximate composition of all important commercial species of fish must be known, since it involves only the simplest techniques well understood for over half a century. Despite this argument, I kept finding evidence that the erroneous value for the oil content of mackerel was not an isolated instance; in fact, for some important species, I could find no data on proximate composition at all. Accordingly I have had great interest since that time in learning more about this subject.

Our laboratory at Seattle is at present engaged in a long-term investigation of proximate composition. We, of course, recognize that other information on more specific components in fish is needed, and in fact we are investigating some of these components, such as the fatty acids contained in fish oils. Yet we believe that a knowledge of proximate composition is so basic to many problems that more information should be obtained on it as well.

The main obstacle to establishment of proximate composition figures has been the relatively large variation in values, especially for the oil content, from species to species and also for individual fish or lots of fish of the same species taken at different times or under different conditions. This variation is so great that in many (perhaps most) instances in which proximate composition has been reported in the literature for a certain species, the results are not representative, but are merely analyses of a few isolated lots with little relationship to the true average composition. In fact, average values for proximate composition of fish often have little meaning. What is needed is the establishment of ranges of values.

Some of the most complete investigations of proximate composition of fish were made nearly a century ago. Atwater (1), during the 1880s, carried out a comprehensive survey of proximate composition of about 65 species of American food fish. Miescher (5), about 1870, carried out an exhaustive study of the composition of Rhine salmon during the spawning migration.

Most present-day ideas about such old studies are that the analytical methods were unreliable. This belief is untrue. To prevent oxidation, for example, Atwater dried his samples under hydrogen before extracting the oils. The only valid criticism of these earlier studies is that the importance of variation from sample to sample within a species was not recognized, and in many instances either too few samples, or samples taken at a season not representing commercial operations, were analysed. On the other hand, owing to less restrictions on lengths of reports, these earlier papers give full details as to the history of the samples used.

Much of the analytical data on proximate composition accumulated in recent years for fish has been published in such a way that it is impossible to determine whether adequate samples were used. This statement is especially true for many reviews (3, 8, 9) in which averages and ranges are cited without giving any indication of the sampling procedures. Sometimes ranges are quoted that are based upon analyses of only two samples.

The purpose of the present article is to discuss (i) variation in the composition of fish, (ii) the causes for the variation, (iii) the application of proximate composition knowledge, (iv) the vitamin and the mineral content of fish, and (v) the needs for future work.

No attempt will be made to give tables listing values of proximate composition of various species because, in my opinion, current knowledge is not complete enough to permit compilation of the values in anything like final form. Although proximate composition normally refers to analyses for protein, oil, moisture, and ash only, brief consideration will be given, on a general basis, to mineral and vitamin content.

Variation in composition of fish

Table I gives the ranges and "average" proximate composition for the edible portion of fish without regard to differences in species. A very wide range of more than 300-fold occurs in the oil content. Moisture, protein, and ash contents exhibit much smaller variation of less than five fold.

TABLE I

Proximate composition of edible portion of fish

Statistic calculated	*Moisture*	*Protein*	*Oil*	*Ash*
	%	%	%	%
Average . .	74·8	19	5	1·2
Range . .	28–90	6·0–28	0·2–64	0·4–1·5
Ratio high to low	3·2	4·7	320	3·8

Note: By "edible portion of fish" is meant the skin-free and bone-free fillet.

We can arbitrarily consider that (i) when the content of oil in the fish is under 5 per cent, the species is of low oil content; (ii) when between 5 and 15 per cent, of medium oil content; and (iii) when above 15 per cent, of high oil content. Similarly, we can arbitrarily consider the protein content of fish to be low if it is less than 15 per cent, and high if between 15 and 20 per cent. In the few instances when the protein content lies above 20 per cent, we can consider it to be very high.

Most species of fish have, using these criteria, either low oil and high protein (category A, Table II) or medium oil and high protein (category B, Table II). Three other categories occur occasionally. In category C, fish may have high oil and (usually) low protein; in category D, low oil and very high protein; and in category E, low oil and low protein. Although these are arbitrary divisions that sometimes overlap, they furnish a convenient basis for classifying proximate composition of fish.

Category A, in which fish have low-oil and high-protein content, is the category in which most fish are found. Many of the species in this category have oil contents near the bottom of the range; that is, nearer to zero than to 5 per cent. The oil content of the edible flesh for most of the species in category A averages 2 per cent or less,

TABLE II

Types of fish

Category	*Type of fish*	*Prototype*				
		Species	*Moisture* %	*Protein* %	*Oil* %	*Ash* %
A	Low oil—high protein (under 5%) (15–20%)	Pacific cod *Gadus macrocephalus*	81·5	17·9	0·6	1·6
B	Medium oil—high protein (5–15%) (15–20%)	Mackerel *Scomber scombrus*	67·5	18	13	1·5
C	High oil—low protein (over 15%) (under 15%)	Siscowet lake trout *Cristivomer namacush siscowet*	52·5	11·3	36·0	0·53
D	Low oil—very high protein (under 5%) (over 20%)	Skipjack tuna[1] *Katsuwonus pelamis*	72·4	26·2	0·7	1·5
E	Low oil—low protein (under 5%) (under 15%)	Butter clams *Saxidomus nuttall*	83·0	13·3	1·3	1·9

[1] Analysis of light meat only. This part is the only one that is ordinarily canned.

some important species containing well under 1 per cent. Most crustaceans fall into this category.

Category B, covering species with oil contents between 5 and 15 per cent, includes a majority of the species not in category A. Although meat from farm animals is considered to be relatively lean, it contains 5 to 15 per cent oil, and accordingly would be placed in category B. There are almost no meats so lean as to correspond to category A, the low-oil-content category in which most fish are found.

Category C consists of fish of high oil content and unusually low protein. Like category A, it includes some fish that ordinarily would fall in category B. The oil content, for example, of fish in category B varies quite widely, so that occasionally species normally in category B will contain less oil than usual and accordingly will fall into category A. More frequently, some of the species normally in category B will average higher than 15 per cent oil. Since the protein content then also declines, these fish will correspond to category C. Few species, however, are so oily as invariably to fall in category C.

Category D consists of species having unusually high protein content (over 20 per cent) and low oil content. Although only a few species fall into this group, several very important ones, such as tuna and halibut, are included in it.

Category E, covering fish low in both oil and protein, includes primarily certain shellfish such as oysters. A few of the species that normally fall in category A may have sufficiently reduced protein content to push them into category E. Thus most flounders are in category A, but have a protein content near the lower (15 per cent) level. At certain seasons when levels of protein decline, some flounders may fall into category E.

Table III indicates the category into which many of the important species of fish fall. As indicated above, for any given species, there may be overlapping into more than one category. When this overlapping is frequent, the fact has been noted under the column headed "remarks" in Table III.

Because my experience with proximate composition of fish is limited to those of North America, there are many important species in other parts of the world with which I am unfamiliar. Accordingly, Table III is far from complete with respect to coverage of species. Rather, it shows how the categories outlined in Table II can be applied to some of the commercially important species.

Another type of variation in proximate composition of fish occurs between different parts of the edible flesh.

TABLE III

Types of composition of some important species

Species	*Category*	*Remarks*
Anchovies	B	Some caught at certain seasons or in certain localities may fall in category C
Carp	A	Some caught at certain seasons or in certain localities may fall in category B
Cod	A	
Flounder	A	
Haddock	A	
Hake	A	
Halibut	D	
Herring	B	Some caught at certain seasons or in certain localities will fall in category C
Mackerel	B	Some caught at certain seasons or in certain localities may fall in category C
Mullet	A	Borders on category B
Ocean perch	A	
Pollack	A	
Rockfishes	A	
Salmon	B	Some species of salmon, chum (*Oncorhynchus keta*), Atlantic (*Salmo salar*), and pink (*Oncorhynchus gorbuscha*) may border on category A
Sardines	B	Some caught at certain seasons and in certain localities may be category C
Tuna	D	Albacore tuna (*Germo alalunga*) when caught in certain areas is in category B. Bluefin tuna (*Thunnus thynnus*) borders on category B
Whiting	A	
Clams	E	
Crabs	A	
Oysters	E	
Scallops	A	
Shrimp	A	

Category A = oil <5%, protein 15–20%; category B = oil 5–15%, protein 15–20%; category C = oil >15%, protein <15%; category D = oil <5%, protein >20%; and category E = oil <5%, protein <15%.

This variation may be from one part of the fish to another—for example, from the head to the tail; or it may be a variation in composition of various types of tissue—for example, light muscle and dark muscle or depot fat areas.

There is generally an increase in oil content of the muscle in progressing from the tail portion toward the head (Table IV). This trend is more marked in relatively oily species of fish.

TABLE IV

Variation in oil content of edible flesh of pink salmon (*Oncorhynchus gorbuscha*), from head to tail portion (6)

Portion	*Moisture* %	*Protein* %	*Oil* %	*Ash* %
Nape . . .	75·9	18·8	4·8	1·1
Center . .	76·2	19·8	3·5	1·2
Tail . . .	77·2	19·9	2·6	1·2

Note: By "edible flesh" is meant the skin-free and bone-free fillet.

With most species, two types of tissue, the light and the dark, occur. Dark tissue may be found, for example, in the flesh along the lateral line. The proximate composition of this dark muscle (Table V) is generally considerably higher in oil, and lower in moisture and protein, than is that of the light muscle.

TABLE V

Proximate composition of light and dark tissue of edible flesh of pink salmon (*Oncorhynchus gorbuscha*) (6)

Type of tissue	*Moisture* %	*Protein* %	*Oil* %	*Ash* %
Light . . .	77·4	20·4	2·1	1·25
Dark . . .	69·9	17·5	12·5	1·20

Note: By "edible flesh" is meant the skin-free and bone-free fillet.

Fatty tissues comprising primarily oil occur in certain portions of the fish, notable in layers just beneath the skin. The proximate composition at such sites is obviously quite different from that elsewhere in the fish.

There is an apparent inverse relationship between the oil and moisture content of fish, such that the sum of the moisture and oil percentages approximates 80 per cent. The summation of oil and water, however, is not necessarily constant; it may, in rare instances, exceed 90 per cent, and it frequently spans a range of 78 to 85 per cent.

This relationship may be largely fortuitous. Obviously, in a sample having a very high content of oil, some components must be less than average to give the total of 100 per cent for all components. Even if all other components were decreased proportionately to their content in order to compensate for the higher oil content, the major share in the decrease would be reflected in decreased moisture content which, of course, is the major component, being ordinarily about four times as high as the others. Actually, in most cases in which a high content of oil occurs, both moisture and protein contents are lower than average. With samples of extremely high oil content, the protein content may be less than 10 per cent.

Causes of variation in proximate composition

Although we customarily relate proximate composition to such factors as geographical area or season of the year at which the fish are taken, the ultimate cause of variation is primarily due to feed intake and to other related factors such as metabolism efficiency of the individual fish and the energy expenditure resulting from more or less active movement of the fish.

Factors governing feed intake include such causes as (i) overstocking of fish within restricted waters thus limiting available feed, (ii) decrease or increase in normal amount of feed in the habitat of the fish, and (iii) failure of the fish to consume feed, as during the spawning migration.

As was pointed out earlier, oil is the component showing the greatest variation in fish. In mammals, the fat content of the animal is correlated closely to feed intake. It has been shown by Brown and Tappel (2) that pathways of fat metabolism in fish follow closely that of fat in other members of the animal kingdom. There is accordingly little reason to doubt on theoretical grounds that a relationship between the feed intake of fish and their proximate composition exists. The relationship is substantiated by many general observations. These include the well-known fact that, preceding the spawning migration of such fish as salmon, the oil content increases during feeding, and that during the migration period, when no feed is ingested, the oil content decreases markedly. In the late stages of the migration, the protein content also markedly decreases.

Recent experiments at Torry Research Station (4) showed that, when live cod are starved by confining them without feed, the flesh develops a characteristic milky consistency, and the oil content declines.

The content of oil in sheepshead, a lake fish, has been shown in our studies to be closely correlated with the availability of feed. Samples taken in overstocked, small lakes, where feed is not sufficiently available, had average oil contents of less than 1 per cent. Samples taken from rivers or large lakes where there was ample feed had average oil contents of 6–10 per cent.

Thus both oil and protein content of fish can vary widely, depending upon the feed ingested. This factor, in turn, may be dependent upon natural feeding habits of various species of fish, availability of feed under local or temporal conditions, or upon some feeding habit such as that pertaining to fasting during the spawning migration.

Applications of proximate composition knowledge

The obvious application of knowledge on the proximate composition of fish has always been needed by dieticians in institutions concerned with mass feeding and by individuals interested in caloric content of foods for weight control.

Recently, study of the relationship between the type of fats ingested and arteriosclerosis, and the need for control of obesity, has made a knowledge of the proximate composition of fish in demand by heart specialists. Many of the specialists are recommending that their patients use generous quantities of fish in the diet, both as a means of avoiding excessive consumption of saturated fatty acids and as a means for the patient to obtain adequate protein in the diet without taking in excessive fat, which might result in their becoming overweight. A better knowledge of proximate composition of fish is needed to enable fish to be prescribed in such instances.

Human dietary considerations are by no means the only reason why a knowledge of proximate composition of fish is required. Processors of animal feeds in which fish is incorporated also need a knowledge of proximate composition. Often they are interested in the composition of the whole fish. Thus, canners of cat or dog food frequently incorporate whole industrial fish in their products. These products are standardized to close tolerances in protein and fat content. An accurate knowledge of seasonal and geographical variation of the available species of fish is needed in order for them to schedule the use of fish in such products. Similar considerations apply to the utilization of industrial fish in the feeding of fur-bearing animals.

Processors of fish for making fish meal and oil need a knowledge of proximate composition for predicting oil yield. Similarly, preparation of fish flour and of other dried fishery products requires knowledge of proximate composition to determine if the yield of protein will be great enough to make the operation economically feasible.

Vitamin and mineral content of fish

Data on proximate composition of fish is quite voluminous, even though it is usually not adequately documented as to sampling. Data on the content of other components that occur in lesser amounts is relatively meager. In this section, the content of minerals and vitamins in fish will be discussed briefly. Because of the paucity of data, no attempt will be made to discuss the content of such substances according to species, but rather only as to the content in fish in general. This statement is not to imply that there is no species variation. Undoubtedly there is, and it may be a large variation. In the absence of data to delineate such difference, the results can only be presented in a general way.

Table VI presents data on the content of some vitamins in fish. As noted in the table, data on certain vitamins are so meager as to render any positive interpretation uncertain. The column headed "usual range" gives the best estimate of the range *ordinarily encountered*, from which any extreme values—perhaps encountered only in very unusual, non-commercial species—have been eliminated.

Contents of the oil-soluble vitamins (A, D, and E) are shown in Table VI as the content in the flesh. The amounts shown apply only to species containing at least 5 per cent oil. Many of these species (for example, cod) contain considerable quantities of these vitamins in the liver. In fact, lean species often contain far more of the fat-soluble vitamins in the liver than many of the more oily species contain in the flesh.

TABLE VI

Vitamin content of edible flesh of fish

Vitamin	*Units*	*Content*	
		Average	*Usual range*
Vitamin A[1] . .	μg. %	25	10–1,000
B vitamins			
Thiamine. .	μg. %	50	10–100
Riboflavin .	μg. %	120	40–700
Nicotinic acid .	mg. %	3	0·5–12
Vitamin B_{12} .	μg. %	1	0·1–15
Pantothenic acid	mg. %	0·5	0·1–1·0
Pyridoxine[2] .	μg. %	500	50–1,000
Biotin[2] . .	μg. %	5	0·001–8
Folic acid[2] .	μg. %	80	71–87
Vitamin C . .	mg. %	3	1–20
Vitamin D[1] . .	μg. %	15	6–30
Vitamin E[1, 2] . (total tocopherol)	μg. %	12	4–35

[1] For fish of medium or high oil content.

[2] Based on very scanty data.

Note: By "edible flesh" is meant the skin-free and bone-free fillet.

Some of the visceral organs also contain larger quantities of certain of the B vitamins than does the flesh. This distribution is particularly true for riboflavin and vitamin B_{12}.

In general, the content of the various B vitamins in the flesh of fish approximates to that in various meats, and the content of vitamins A, D, and E is higher for species containing considerable oil content. Vitamin C is not contained in fish to a large enough extent to be an important source of this vitamin.

TABLE VII

Mineral content of edible portion of fish

Mineral	*Average content mg. %*
Potassium	300
Chloride	200
Phosphorus	200
Sulfur	200
Sodium	63
Magnesium	25
Calcium[1]	15
Iron	1·5
Manganese	1
Zinc	1
Fluorine	0·5
Arsenic	0·4
Copper	0·1
Iodine	0·1

[1] Values are much higher (about 200 mg. %) for calcium in canned fish, since the bone is included.

Note: By "edible portion of fish" is meant the skin-free and bone-free fillet.

Table VII lists the minerals found in fish to extents of 1 mg. per cent or more. Some reports also show silicon to be present to an extent of about 2 mg. per cent, but this concentration has not been sufficiently checked to be confirmed.

Many elements occur in trace amounts (less than 1 mg. per cent). Only four of these (fluorine, arsenic, copper, and iodine) are listed in the table. In addition, almost all the elements that occur in sea water are found to some extent in fish. These elements include aluminium, barium, chromium, cobalt, lead, lithium, silver, strontium, titanium, and vanadium.

No variation in content of the various minerals is shown in Table VII. In fact, as with other components, considerable variation occurs; but in most cases data in the literature are too meager to permit even approximate ranges to be indicated.

A knowledge of the variation of the sodium content of fish is doubtless more important than is that of any other mineral constituent because of the importance to dieticians in hospitals and to others to be able to set up low-sodium diets. Thurston and Osterhaug (7) have reported quite extensively on this variation. For raw, unprocessed fish, sodium averages 58 mg. per cent in freshwater with a range of 48–77 mg. per cent for nine species studied. For 21 salt-water species examined, an average of 65 mg. per cent sodium was found with a range of 34–96 mg. per cent. Sometimes fish that have been processed have higher sodium contents because of addition of salt during processing. Thus frozen fish fillets or steaks that had been brine dipped before being frozen contained 165–215 mg. per cent of sodium. Similarly, canned fish to which salt was added contained 590–875 mg. per cent of sodium.

Needs for future work

Our knowledge of proximate composition of fish is still incomplete. The question of how much data are needed for a given fishery or species of fish, in view of the possible wide variation in composition with differing conditions, is difficult to assess. At our Seattle laboratory, we are attempting to obtain at least a minimum knowledge of the proximate composition of fish landed on the Pacific Coast of the United States. Our method consists in analysing from 10 to 16 individual fish of a given species per lot of fish with two or three lots per year obtained over a period of two or three different years. When a high variation of oil content with season occurs, more frequent sampling is made. We sample both the edible portion of the fish and also the non-edible. In many instances, different parts of the edible portion are analysed separately.

Even with these minimum sampling guides, we realize that full information on proximate composition is far from being achieved. Nevertheless, we feel that this is the maximum effort warranted under present conditions.

Assays should be made for many other components besides those considered in proximate composition. Such substances as individual amino acids, fatty acids, and vitamins, however, require much effort and time. Since we believe that a knowledge of proximate composition of fish is basic, we are placing considerable emphasis on it.

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Naturally some changes take place in the palatability and composition of fish according to the methods of processing employed. But sound food value can always be maintained by applying proper methods. The picture shows cod being dried in Greenland for export to tropical areas.

AMINO ACID COMPOSITION OF FRESH FISH AND INFLUENCE OF STORAGE AND PROCESSING

by

FRITZ A. L. BRAMSTEDT

Recent investigation indicates that muscles of fish and shellfish contain large amounts of free amino acids, the pattern of which is characteristic for the different species. Great differences are seen in the amount of the free amino acids only. The protein-bound amino acids show a very uniform pattern.

The uniformity of the pattern of free amino acids makes it possible to investigate the influence of factors such as storage, spoilage and processing on the composition of the free amino acids. Recent investigations showed that the proteolytic and peptidase enzymes in fish muscle play an important part in the degradation of proteins and peptides, especially during the initial stage of storage before the bacterial invasion takes place.

Environmental conditions such as salt concentration of the sea water obviously influence only a few free amino acids, probably those involved in osmo regulation.

Glycine is an important factor for the individual taste of the flesh of different fish species. It seems, however, that there might also be a relation between the individual taste of fish species and the free amino acids in the flesh.

Biochemical changes in the free amino acids of fish muscle have been found occurring in the early stages of ice storage, even under optimal conditions on board modern fishing boats. Investigations showed, for example, that lysine was the subject of the greatest quantitative variations. For example, the content of free lysine in cod muscle increased from 3·73 mg. per cent in first-quality fish to 24·25 mg. per cent in fourth quality. In fish unfit for human consumption the amount of lysine decreases in proportion as the malodorous substances increase. In order to obtain perfect preservation of fish flesh, it is essential to inhibit fish muscle enzymes.

Although deep freezing is a very effective method for inhibiting enzymes, it was found that cod muscle enzymes were still active at − 17°C.

In ice storage the amount of free amino acids decreases until the fifth or seventh day, but increases when bacterial activities start. Investigations have shown that free β-alanine occurs in cod muscle just after the fish has passed rigor mortis, and that most of it derives from de-carboxylation of aspartic acid. Very little is known about the influence of various processing methods on amino acids in fish muscle, and further work is urgently necessary. The same applies to the action of fish muscle enzymes, especially during the initial stages of spoilage.

LA COMPOSITION EN AMINO-ACIDES DU POISSON FRAIS ET L'INFLUENCE DE L'ENTREPOSAGE ET DU TRAITEMENT

Des travaux récents indiquent que les muscles des poissons, crustacés et coquillages contiennent des quantités importantes d'amino-acides libres, dont la répartition relative est caractéristique pour les diverses espèces et dont le montant seul présente de grandes différences. Les amino-acides liés aux protéines montrent une répartition très uniforme.

L'uniformité de la répartition relative des amino-acides libres fait qu'il est possible d'étudier l'influence qu'ont sur leur composition des facteurs tels que l'entreposage, l'altération et le traitement.

Des études récentes ont montré clairement que les enzymes protéolytiques et les peptidases du muscle de poisson jouent un rôle important dans la dégradation des protéines et des peptides, spécialement au cours de la période initiale d'entreposage avant l'invasion bactérienne.

Les conditions de milieu, telles que la concentration saline de la mer, n'influencent nettement que quelques amino-acides libres, probablement ceux qui sont mis en jeu par la régulation osmotique.

La glycine est un facteur important de la saveur particulière de la chair dans les différentes espèces de poisson. Il semble cependant qu'il puisse y avoir une relation entre la saveur particulière d'une espèce de poisson et les amino-acides libres de sa chair.

Des changements biochimiques dans les amino-acides libres du muscle de poisson apparaissent au cours des premiers stades de l'entreposage sous glace, même dans des conditions optimum, à bord de bateaux de pêche modernes. Les études ont montré, par exemple, que la lysine était sujette à de grandes variations quantitatives. Ainsi, la teneur en lysine libre du muscle de morue s'accroît de 3,73 mg. % g. dans le poisson de première qualité à 24,25 mg. % g. dans celui de quatrième qualité. Dans le poisson impropre à la consommation humaine, la teneur en lysine décroît alors que les substances malodorantes augmentent. Afin d'obtenir une conservation parfaite de la chair de poisson, il est indispensable d'inhiber les enzymes du muscle de poisson.

Quoique la congélation à coeur soit une méthode très efficace pour inhiber les enzymes, on a trouvé que les enzymes du muscle de morue étaient encore actives à − 17°C.

Au cours de l'entreposage sous glace, le montant des amino-acides libres décroît jusqu'au 5e-7e jour, mais s'accroît lorsque l'activité bactérienne démarre.

Des études ont montré que la β-alanine libre apparaît dans le muscle de poisson juste après que le poisson ait dépassé la rigor mortis et qu'elle dérive en grande partie de la décarboxylation de l'acide aspartique. On sait peu de chose sur l'influence des diverses méthodes de traitement à l'égard des amino-acides dans le muscle de poisson, et un travail ultérieur est, d'urgence, indispensable. Ceci s'applique également à l'action des enzymes du muscle de poisson, spécialement au cours des périodes initiales de l'altération.

LA COMPOSICION DE LOS AMINOACIDOS DEL PESCADO FRESCO Y EFECTO DEL ALMACENAMIENTO Y EL TRATAMIENTO

Investigaciones recientes indican que el tejido muscular de pescados y mariscos contiene grandes cantidades de aminoácidos libres, cuya distribución es característica para las diversas especies, en tanto que sólo se aprecian grandes diferencias en la cantidad de aminoácidos libres. Los aminoácidos ligados a las proteínas muestran una distribución muy uniforme.

La uniformidad de la distribución de aminoácidos libres hace factible investigar el efecto que factores como el almacenamiento, deterioración y elaboración tienen en su composición. Investigaciones recientes han puesto de relieve que los enzimas proteolíticos y las peptidasas del tejido muscular del pescado desempeñan un papel importante en la degradación de proteínas y péptidos, particularmente durante los primeros momentos del almacenamiento, antes de la invasión bacteriana.

Condiciones ambientales, como la concentración salina del mar, es evidente que sólo influyen en unos pocos aminoácidos libres, probablemente los que participan en la regulación osmótica.

La glicina es un factor importante en el sabor particular de la carne de diferentes especies de pescado; pero también parece existir una relación entre el sabor individual de una especie de pescado y los aminoácidos libres de su carne.

Los cambios bioquímicos en los aminoácidos libres del tejido muscular del pescado aparecen en los primeros momentos del almacenamiento en hielo, incluso en condiciones óptimas a bordo de pesqueros modernos. Las investigaciones han demostrado, por ejemplo, que la lisina está sujeta a las mayores variaciones cuantitativas. Así, el contenido de lisina libre en el tejido muscular del bacalao aumenta de 3,73 mg.% en el pescado de primera calidad, a 24,25 mg.% en el de cuarta. En el pescado no apto para el consumo humano, la cantidad de lisina disminuye, en tanto que las substancias malolientes aumentan. Con objeto de obtener una conservación perfecta de la carne del pescado, es indispensable inhibir los enzimas del tejido muscular.

Aunque la congelación a fondo es un método muy eficaz para inhibir enzimas, se ha observado que los del tejido muscular de bacalao continúan activos a — 17°C.

Durante el almacenamiento en hielo, la cantidad de aminoácidos libres disminuye hasta el 5° ó 7° días, pero aumenta cuando se inicia la actividad bacteriana.

Las investigaciones han demostrado que la β-alanina libre aparece en el tejido muscular del pescado inmediatamente después de cesar la rigidez cadavérica, y que casi toda se deriva de la decarboxilación del ácido aspértico. Se sabe muy poco de la influencia de los diversos procedimientos de elaboración en los aminoácidos del tejido muscular del pescado, y es urgente realizar investigaciones ulteriores. Lo mismo se puede decir de la acción de los enzimas del tejido muscular del pescado, particularmente en las fases iniciales de la alteración.

RECENT investigations have shown, that fish muscle, like sea food, contain high amounts of free amino acids (3, 12, 25, 27) varying from 1 to 5 g. compared to 100 g. protein-bound. In sea food from 7 to 12 g. free amino acids were found. So invading bacteria find sufficient free amino acids for growth and reproduction. This fact and the low content of connective tissue, just as the high water content, might be responsible for the rapid spoilage of fish.

Comparing the chromatograms from 30 different fish species in our laboratory revealed a uniformity of pattern (25). This corresponds with Florkin's results (9). The above-mentioned changes under influence of different salt concentrations and temperature of the surrounding media are important enough to change the pattern in principle. This was confirmed by Japanese authors (13). Beside these factors, seasonal variations were found in some amino acids. The differences in the pattern are not as important as the quantity of the free amino acids, estimated as alfa-amino-nitrogen by the classical van Slyke method.

Beside free and protein-bound amino acids, fresh-caught fish has peptide-bound ones as well, which can be detected by hydrolysis of the supernatant after precipitation with alcohol in a final concentration of 85 per cent. After hydrolysis with hydrochloric acid, an increase of 10 different amino acids in the chromatogram could be seen, if compared with that before hydrolysis. These amino acids were: glutamic acid, aspartic acid, histidine, lysine, beta-alanine, leucine, iso-leucine, phenylalanine, and valine, and an unknown amino acid (fraction 2). Florkin (9) saw an increase of the following free amino acids after hydrolysis of the supernatant of carp muscle: glutamic acid, aspartic acid, valine, phenylalanine, leucine, iso-leucine and lysine after precipitating with tungstate. The single difference with our findings was that he found a decrease in free histidine.

Siebert and co-workers found that substrates such as L-Leucyl-glycine, L-Lysyl-glycine, L-Histidyl-L-histidine, L-Leucyl-L-tyrosine, L-Leucyl-glycyl-glycine, L-Leucyl amide, Glycyl-L-glutamate, Glycyl-L-histidine, Glycyl-L-valine and others were split by cod muscle extract. The results show that in cod muscle peptidases are active splitting compounds containing the amino acids listed above. As far as it has been investigated at present, the same amino acids are found in the hydrolysed supernatant.

To sum up, the pattern of free amino acids is characteristic for the different species, while strong differences are seen only in the *amount* of free amino acids. The protein-bound amino acids show a very uniform pattern, even if belonging to different families. In spite of these results the protein of the fish muscles of different species can be separated electro-phoretically into different components (7, 26) which are characteristic for the different species. The paperchromatogram shows that the mean value for the various amino acids is nearly uniform with regard to the different species.

In the hydrolysed supernatant we only get the mean concentration of the single amino acid, which is equal for the various species, but may be a part of the single electrophoretic fractions in various amounts.

Proof by several authors of a uniform pattern of free amino acids, with only few characteristic exceptions, enables us to look for changes under the influence of various factors such as storage, spoiling and processing, etc.

These investigations were facilitated by using an improved disk chromatography method developed by E. Ranke in our laboratory. This method enables us in about 2–3 hours to compare up to 8 different samples. Differences in the paper chromatogram can be seen easily also by persons not trained in paperchromatography. This method helped us easily to select those samples showing extreme differences compared with the chromatogram of fresh-caught fish (3).

For further and exact analysis, two-dimensional chromatography was used. All quantitative estimations were performed by microbiological methods, which have been used in our laboratory for more than ten years. The turbidimetric estimation was chosen.

Quite a new aspect was brought into discussion when the rôle of fish muscle enzymes as spoiling agents was discussed (2, 3, 4). Siebert, and Siebert and Schmitt (30, 31, 32) investigated the activity of fish muscle proteolytic and peptidase enzymes and could demonstrate that the activity of the enzymes is so high that they play an important rôle in degradation of proteins and peptides. These results show convincingly that in future the rôle of fish muscle enzymes should be considered as an important factor in spoilage, especially in the initial stages before bacterial invasion takes place. The data about changes in the amino acid pattern in fish (whether induced by bacteria or without them) are poor. Shewan and Jones (29) compared free amino acids in sterile and spoiling cod muscle and found differences in the content of various amino acids during storage from 0 to 20 days. Lysine showed a constant increase in spoiling muscle, but a decrease in sterile muscle; while glycine was unaffected in sterile, but showed a constant increase until the 15th day of storage, followed by a slow decrease. The glutamic acid was the only one of the investigated amino acids in sterile muscle that showed a constant rise. In spoiling muscle the glutamic acid dropped at about the second day to a lower value, then rose to about twice the initial content and remained constant until the 20th day of storage. Alanine showed a similar curve in spoiling muscle, while this amino acid in sterile muscle decreased constantly. These results demonstrate that amino acids in sterile muscles are transformed to other compounds. Though Siebert with his paperchromatography technique could not demonstrate a decarboxylase activity in cod muscle, the results of Shewan and Jones suggest there are in existence enzymes capable of inducing amino acid degradation in sterile cod muscles. The constant and strong increase of free lysine in spoiling cod could be confirmed in my own investigations about the influence of transport of fish in fishing vessels (5). Siebert's results showing that L-Lysyl-glycine is split very rapidly by cod muscle peptidases, correspond excellently with those results. Florkin (9) estimated the free amino acids in different species of evertebrates and vertebrates. The conclusion from his results was that each species has a characteristic "amino acid pool" in the cells, which demonstrates "the whole intercellular system of non-protein-bound amino acids, which exists in a specific pattern for each species and can be regarded as widely constant". It was this pool which we examined in our investigations about the content of free amino acids in fresh-caught fish. Only some few amino acids show quantitative fluctuations, if some environmental conditions are changing. Ranke (25) proved in his thesis that some of the free amino acids take part in osmoregulation, so that quantitative differences will be observed in fish of the same species coming from zones of different salt concentration. In flat-fish he found that especially glutamic and aspartic acid increases if the salt concentration of the surrounding water increased. This corresponds with Florkin, who found in *Eriocheir sinensis* an influence on some amino acids of the intercellular pool by varying temperatures and salt concentrations.

Among other compounds, amino acids are responsible for the taste of fish flesh, as Simidu and Hujita (33) proved. They found glycine especially important for the individual taste of different fish species. Our present knowledge about the rôle of free amino acids in the specific taste of the different fish is very poor. Some more is known about degradation products of different amino acids as malodorous substances in spoiling fish, which will be discussed later. Our investigations about the pattern of different species have demonstrated that some have extremely high amounts of free acids. Such is *Lucioperca lucioperca*, an exception in the family of the Percidae, which has about double the amount of free amino acids as other species. The amino nitrogen, estimated by the van Slyke method, showed for this species 103·8 mg. per cent, for *Acerina cernua* 66·6 mg. per cent and for *Perca fluviatilis* in the mean 67·0 mg. per cent. It is still unknown, if the good taste of *Lucioperca*, which is preferred by many gourmets, is due to its high content of free amino acids. Besides these quantitative differences the Percidae had a higher content of free cystine than other seafish.

On board the fishery research boat of the German Federal Republic, *Anton Dohrn*, fish were prepared for investigation into the changes of free amino acids before and after rigor mortis and into the influence of storage and transport to the different fishing ports in Germany. These investigations are still going on, especially also the control of changes under "normal" conditions on the fishing vessels. Further the influence of storing in the harbour, the transport to the factories and the various processing methods were studied. In spite of the fact that the whole material is not yet analysed, we have got some very interesting preliminary results, which will be discussed here.

The paperchromatograms before and after rigor mortis show important differences. The number of ninhydrine stainable spots increases. Amino acids as methionine, tyrosine, lysine and the three aminobutyric acids, as well as proline and hydroxyproline, are found as new spots *after* rigor mortis has passed. The occurrence of methionine, tyrosine, γ-butyric acid in particular, as well as proline and hydroxyproline, seems to indicate that in the interval between catching and rigor mortis fish muscle enzymes must have been splitting off those amino acids from higher molecular compounds of polypeptide or protein character. In later stages these amino acids vanish again, perhaps by the action of decarboxylating or desaminating enzymes. Their occurrence in later stages of storage and spoilage, especially of tyrosine, methionine, γ-aminobutyric acid, proves the quality is rapidly decreasing. These above-mentioned amino acids are not present in the chromatogram of fresh-caught fish.

These results demonstrate that biochemical changes in the pattern of free amino acids occur in the earliest stages just after catching and storage, even under optimal conditions on board modern vessels. It is often observed that the optimal taste of deep-frozen fish is only obtained if a distinct time has passed before deep freezing, in comparison with the time necessary for meat of homoiotherm organisms to obtain the optimal taste. It is obvious that the time is much shorter for fish (16). It is known that during a comparable space of time several steps of degradation leading to nitrogen containing compounds deriving from amino acids are responsible for the optimal taste in meat (4). Corresponding data for fish are very poor. Here a broad field is open for investigations with modern methods (gaschromatography, etc.).

Conditions during transport on ice from catching areas to harbors are not optimal for preserving the original quality of fresh-caught fish. After being brought from the vessels or fishing boats, fish are stored for several hours, awaiting inspection by the veterinary authorities in the German fishing ports. Fish are divided into five different quality classes. In spite of storage on ice, this time will not be unimportant for the further fate of the stored fish. Since several hours go by before transportation to factories, crowds of people nearby will enhance the possibility of bacterial infection.

In investigations not yet complete we estimated the changes in free amino acids of fish muscle of different species after the transport by the vessels or boats. The time for transportation lasted from 11 to 17 days. The storage on ice could not inhibit biochemical changes. It is known that neither storage on ice nor deep freezing can inhibit enzyme activity totally. Depending upon the temperature used, a more or less effective inhibition will take place, which can be seen by the changes of the pattern of free amino acids in the fish muscle. The pressure inside the vessels and the boats, caused by the storage, will result in mechanical damage, which will help bacteria to invade faster, just as the expressible fluid with its protein and amino acid content will serve as an excellent medium for growth and reproduction of invading bacteria. The parallel liberation of structure-bound enzymes will further act to decrease quality (31).

The amino acids mainly involved were found to be: Lysine, leucine, isoleucine, histidine and tyrosine. The paperchromatograms showed changes in the amounts of these amino acids in free form in the different qualities, as well as in fish from the first and last catching periods. These findings correspond extremely well with the organoleptic control of the veterinary officers at the fishing port. The amino acid showing the greatest differences was lysine. In cod it rose threefold with decreasing quality (Class I–IV). The content of free lysine increases in cod muscle from 3·73 mg. per cent in first quality to 24·25 mg. per cent in the fourth quality. This corresponds to the results of Shewan and Jones in spoiling cod muscle. Also other seafish species showed a rapid metabolism of lysine. In qualities unusable for human food the lysine content lowers again, which results in an increasing degradation to malodorous substances (5). To this group of compounds belong piperidine, N-aminopiperidine, cadaverine and putrescine, the latter occuring in the latest stages of spoiling (4). Also pyridine, detected in fish skin by Japanese authors (22, 23) can be obtained by degradation of lysine.

The amino acids leucine, isoleucine and valine are substances which can degenerate into malodorous compounds, as isovalericaldehyde, crotonaldehydedelta, aminovalericacid and methylmercaptopropylalcohol (22, 23). Corresponding to these data we found in our investigations a rapid metabolism of the free amino acids mentioned above. The content in the different qualities as well as in fish transported in fishing vessels for different times varied highly. The behaviour in the different species was not equal, which suggests the possibility that the enzymes are changing in activity in the various fish, or that the equipment is different with respect to the peptidases. There also a broad field is open for further research. All these facts show that the degradation of free amino acids, and the splitting of peptides and proteins, begins just after the fish has been caught. The initial stages of amino acid degradation must be due to fish muscle enzymes, as no bacterial invasion has taken place at that time. The next step will be to investigate the action of Siebert's isolated enzymes on the isolated proteins, peptides, etc., of the different fish muscles.

These preliminary results demonstrate quite obviously that perfect preservation will only be possible if we succeed in inhibiting the fish muscle enzymes.

In recent years deep freezing has been regarded as the optimal method for retarding spoilage and keeping the quality of fresh-caught fish. Many facts have shown that it is not possible to inhibit the enzyme action completely, so that no biochemical changes would occur under storage, even at the very low temperatures used in deep freezing.

In our own investigations on rainbow trout prepared after a special method for export to the U.S.A. from Germany, we saw a constant increase of residual nitrogen during a storage period up to 10 months. Compared with fresh-caught trout, the residual nitrogen rose from 86·7 mg. per cent to 198·5 mg. per cent after 10 months. This increase is not only due to liberation of amino N from amino acids, as the changes in free amino acids showed. Earlier investigations have clarified that there is a very active guanine deaminating enzyme in the skin of many fish. The storage temperature was constant in the range from −22°C. to −25°C. This phenomena—the increasing residual N—seems difficult to explain, as enzyme action needs non-frozen water. Now Dyer, Frazer, Ellis and MacCallum (8a) found that at −18°C. 6·5 per cent of the total water of fish fillet is present as liquid (non-frozen) water. At −9·4°C. 10 per cent of the total water is still liquid. So enough water will be present for enzyme action also in deep-frozen fish. Siebert (32) was able to show in some of his experiments that enzymes of cod muscle were still active at −17°C.

Storage of whole fish as well as fillets on ice at temperatures of about +2°C. to +4°C. change the original free amino acid pattern very soon (27, 28). The first days of storage are characterized by a slow, but remarkable, decrease of free amino acids (4). Leucine, isoleucine and lysine showed a constant decrease in fish fillets stored at +2°C. from the 1st to the 5th or even the 7th day of storage, while other amino acids such as cysteine/cystine and arginine showed repeated fluctuations. It is in this period that fillets stored under the above-mentioned conditions produce malodorous compounds, as already discussed earlier. By means of gaschromatography Diemair (8) found highly volatile compounds, which could only be detected by using temperatures as low as −80°C to −190°C. Here completely unknown malodorous compounds could be detected as being important for the "fishy" odor of fish. Many of the undesirable, bad-smelling substances in fish are derivatives from amino acids. After the first days of storage the bacteria invade the fish flesh, now acting together with fish muscle enzymes, so that deterioration goes on faster. This could be demonstrated in a rapid increase of free amino acids, estimated by the van Slyke method. Amazingly, electrophoretic changes in behavior of the different proteins occur much later than the changes in the pattern of free amino acids.

Likewise, the peptides change during storage. While the decrease of free amino acids is seen as well in summer as in winter, the behavior of peptides is different in the different seasons. The peptide amino-nitrogen (van Slyke method after hydrolysis of the supernatant with hydrochloric acid, compared with the amino-nitrogen content before hydrolysis) followed in the first 5 days of storage that of the free amino acids. This indicates that, besides a degradation of free amino acids, a similar one of peptides takes place. The increase after this point of storage in free amino acids corresponds to the decrease of peptide amino nitrogen.

The peptides consisted mainly of the amino acids: glutamic acid, aspartic acid, proline, arginine and lysine. In particular, glutamic and aspartic acids were found in high amounts. The peptide amino-nitrogen was higher than that of the free amino acids in the storage period from the 10th to the 14th day. Later on, until the 22nd day of storage only a little increase of free amino acids was seen, in spite of a rapid decrease of peptides. This indicates that in later stages of spoilage the free amino acids are more rapidly degraded than the peptides are split. These phenomena can possibly be explained by a change in the bacterial flora with another enzyme equipment (6).

A very interesting amino acid is the free β-alanine. As far as was known until recent time no free β-alanine occurs in animal tissues. In fresh-caught cod, only slight traces were seen in the chromatogram. In the initial stages of spoilage, just after the fish has passed rigor mortis, remarkable amounts of free β-alanine are present. During storage the amounts change. Some observations of E. Ranke (27) seem to indicate that traces of free β-alanine are in the chromatograms of many species of fresh-caught fish, in sea fish as well as in freshwater species. It is possible that these traces are not present in the living individual, but occur during the short time in which the fish is prepared for chromatography, especially during homogenization, despite this being performed in the presence of alcohol. The sources can be aspartic acid or anserine or carnosine or dipeptides. The action of an anserinase has been described earlier (11). Decarboxylation of aspartic acid leads to β-alanine. E. Ranke could show that after the 7th and until the 10th day of storage the amount of increasing free β-alanine is parallel to the decreasing free aspartic acid. This indicates that at least the main part of the free amino acid derives from decarboxylation of aspartic acid. β-alanine was never found in protein fractions.

We found the following differences in summer and winter:

(1) a higher content of peptides in stored samples in summer;
(2) a higher decrease of proteins in summer;
(3) a higher decrease of amino-nitrogen in the alcoholic precipitate of the homogenated fish muscle in summer;
(4) a higher content of residual nitrogen in summer.

These results indicate that the spoilage increases in summer by a higher activity of proteolytic enzymes, peptidases and other enzymes degrading free amino acids. In the first days of storage the main part is due to the action of autolysing enzymes, present in the fish flesh itself. As bacteriologists have proved, the main invasion of bacteria into fish begins at the 4th day of storage (6, 12). This action of autolysing enzymes will improve the action of bacterial enzymes (24); for, as Bainsbridge (cited from Partmann) has reported, bacterial enzymes are not capable of attacking native proteins.

Investigations of the behavior of the nitrogen-containing compounds in fish muscle have demonstrated that the initial stages of storage and spoilage are widely independent of the presence of bacteria and their enzymes. The action of fish muscle enzymes is to prepare an optimal medium for growth and reproduction of spoiling microorganisms. In future, therefore, attention should be paid mainly to the initial stages of deterioration and to the nature and conditions under which fish muscle enzymes act. An inhibition of these enzymes will open quite new aspects for preserving the "fresh-caught quality" of sea fish. Deep freezing is the most effective method today, but cannot inhibit the enzymes to such an extent that they cannot cause any quality decrease.

Fish meal is a product widely used in animal feeding and especially poultry feeding. In recent years its use for human food has been often discussed. The bad taste and odor of the final product hindered broader use. Besides this technical problem, it is of interest to look for a possible influence of the processing method on the nitrogen compounds. Biely, March and Tarr (1) investigated the nutritive value of herring meal for poultry feeding, after having been stored for one year at various temperatures (−25°, −21° and −37°C). No effect was observed. In our laboratory B. Ranke (28) analysed the free amino acids of fish meal. Differences were found between the pattern of fresh-caught fish and fish meal manufactured after the usual method in Germany. Quantitative differences were detected. Higher amounts of leucine, valine, lysine, arginine and γ-aminobutyric acid were found in the meal in free form, indicating that hydrolysing processes had taken place during processing. Remarkable decrease was found in the case of threonine, cysteine/cystine and proline compared with fresh-caught fish. The protein-bound amino acids were scarcely affected. In some cases hydrolxymethionine was found in the chromatogram. So we may assume that careful processing of good-quality fish will result in a good product with optimal nutritive value.

Some information is available on the influence of other processing methods on the amino acids, such as canning, etc. All preservation methods took care of inhibiting the growth and reproduction of bacteria, while little or no attention was paid to the action of fish enzymes. The organic acids used have a relatively low pH value in the beginning of processing, while it increases with an increasing amount of solubilizing protein from the muscles, acting as buffer substances. During this process pH values will occur, being optimal for the action of the catheptic enzymes and the different peptidases, as Siebert (l.c.) has found. Our own experiments (unpublished) have shown that herring stored under sterile conditions shows an increase of free amino acids in an amount which could not be explained by the actual pH value, i.e. by weak hydrolysis. The remarkable increase could be explained by the action of the proteolytic enzymes and peptidases of the muscles.

Quite another biochemical situation is present if micro-organisms are involved. During processing there are many possibilities caused by more or less infection, depending upon the different hygienic conditions (14). Some of these micro-organisms (as *Betabacterium buchneri*) are able to provide their energy for growth and reproduction by decarboxylation of glutamic acid (17). Also in these cases an increase of glutamic acid by the action of fish muscle proteases and peptidases provides a good substrate for this species.

Cooking will lead to a loss in the free amino acids, if the outer layers of the muscle cells or the skin are not "closed" by a heat-denaturation and precipitation of their cell proteins. A prolonged cooking and storage in water will lead to a loss of free amino acids, which will lead to a remarkable loss in taste. This point is especially important for the preparation of deep-frozen fish, especially fish fillets. As discussed above, the change in temperature of deep-frozen fish will lead to denaturation of muscle proteins. Non-optimal freezing time will cause cell damage which can be measured by the liberation of DNA-phosphate (15). It is obvious that cell damage causes a liberation not only of DNA but also of enzymes which can be spread rapidly to other parts of the fish, thus enhancing deterioration.

The influence of smoking on the amino acids is widely unknown. The occurring amounts of formaldehyde are able to attack the residues in the protein-molecule or the amino groups of the free amino acids.

At least one other biochemical process, commonly called "browning reaction", should be discussed. Jones (12) gave a review about this important problem. These browning reactions are pure chemical reactions which can perform without enzymes. These chemical processes are controlled by room temperature.

The main types found in food processing are carbonyl-amino reactions, caramelization, oxidation of polyhydroxy compounds, and sugar-acid reactions, oxidation of haem pigment (important for fish preserved with nitric acid and its salts where nitrosomyoglobin is formed (34)), degradation of heterocycle nitrogen compounds. Of importance is especially the amino-sugar reaction. Micheel and Klemer (18) isolated *n*-glycosyl derivatives of glycine, serine and lysine. Such derivatives and condensation products of lysine and sugar are known from milk powder, diminishing the nutritive value of milk. Especially β-amino acids are objects for "browning" reactions. Jones reported some browning reactions in cod, due to L-methylhistidine liberated by the anserinase activity of fish muscle (11) after death. It is degradated rapidly at near-dry conditions to brown products. This reaction accounts for a considerable proportion of the discoloration of dehydrated cod. Also tryptophan is reported to be readily degradated to brownish products at physiological pH and higher temperatures which are used in canning foods. Jones also reports (12) that nitrogen containing heterocycle degradation appears to be important in fish products. The combination of sugars and the free ϵ-aminogroups of lysine cause a reduction in nutritive value (10). All these reactions can be important for fish and fish products in all those processes where sugar is used. Here the free amino acids will react with the sugar hydroxy groups.

To sum up, the free amino acids are important compounds in storage and processing of fish. The relatively high amounts can be degraded by fish muscle and bacterial enzymes to malodorous substances, and so are responsible for a decrease in quality. In processing, the amino acids can be affected by high temperatures and interaction with other compounds, especially sugars, to form brown, discoloring substances. Further research should deal with the rôle of fish muscle enzymes and their action on proteins, peptides and amino acids of fish muscle, especially in the initial stages of spoilage. We can only improve storage and processing if we get further information about the action and optimal acting conditions of the fish muscle enzyme. If we succeed in inhibiting their action from the beginning of storage, we will obtain a higher quality and keep this quality constant until the fish is sold to the housewife. So the increased knowledge of fish muscle enzymes, begun by Siebert, will lead to more effective methods of fish storage and preservation.

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While chemists and bacteriologists are watchful for the results of various methods of processing, practical techniques have to be evolved to achieve satisfactory commercial methods of converting fish into a marketable product. Canning provides a useful method of processing and storing fish, and the picture shows a team of girls in a Japanese factory packing tuna in cans. ***Photo: Courtesy Fishing News International.***

PROTEINS IN FISH MUSCLE

by

JENS W. JEBSEN

(1) The proteins of muscle fibrilles, tropomyosin, actin, myosin and actomyosin: 65 per cent of fish muscle protein (40 per cent in mammals).
(2) The proteins of cytoplasma (enzymes in muscle metabolism), globulin x, myogen, myoglobin: 26–30 per cent of fish muscle protein (35–40 per cent in mammals).
(3) The proteins of the connective tissue, stromaproteins (collagen): 3 per cent of the muscle of teleost; 10 per cent in elasmobranch (17 per cent in mammals).
Group 1: extractable with neutral salt solution of high ionic strength $> 0{\cdot}5$.
Group 2: extractable with neutral salt solution of low ionic strength $< 0{\cdot}15$.
Group 3: not extractable with neutral salt solution, nor in diluted acids and alkalies.

Group 1 has great crystal lattice energy and great dipole moment; this results in great sensitivity towards salt iones.
Group 2 is rich in charged side chains, but has a small dipole moment; this results in a lower sensitivity towards salt iones.
Precipitation of fish proteins: percentage saturation of ammonium sulphate.

Tropomyosin	50–66
Myosin	35–48
Actin	10–20
Actomyosin	28–38

Result of electrophoresis

Both pure actomyosin and pure actin give one sharp peak. Pure myosin gives a broader peak; this may indicate some heterogeneity. Myogen gives 7 components by Tiselius-electrophoresis. Each species of fishes gives a different pattern. Electrophoresis in starchgel gives 12 components at pH 7·5.

Results by ultracentrifuge

Both actomyosin and tropomyosin give one sharp peak. Myosin is not homogeneous. Myogen gives four components.

Crystallized fish protein

Myogen proteins, myoglobin and tropomyosin.

In the white muscle, glycogenic metabolism predominates; in the red muscle (*Musculus lateralis superficialis trunci*), the citric acid cycle probably prevails.

The red muscle (e.g. in tuna) seems to be a passive muscle with a high oxygen metabolism. The white muscle is an active muscle with low oxygen supply.

PROTEINES DANS LE MUSCLE DE POISSON

(1) Protéines des fibrilles musculaires, tropomyosine, actine, myosine et actomyosine: 65% des protéines du muscle de poisson (40% chez les mammifères).
(2) Protéines du cytoplasme (enzymes dans le métabolisme musculaire), globuline x, myogène, myoglobine: 26–30% des protéines du muscle de poisson (35–40% chez les mammifères).
(3) Protéines du tissu conjonctif, stromaprotéines (collagène): 3% du muscle de téléostéen; 10% chez les élasmobranches; (17% chez les mammifères).
Groupe 1: extractible avec une solution de sel neutre de haute force ionique $> 0{,}5$.
Groupe 2: extractible avec une solution de sel neutre de faible force ionique $< 0{,}15$.
Groupe 3: non extractible avec une solution de sel neutre, ni dans les acides dilués et les alcalis.

Le Groupe 1 est d'une grande énergie de réseau cristallin et d'un grand moment dipolaire; ceci se traduit par une grande sensibilité à l'égard des ions salins.

Le Groupe 2 est riche en chaînes à charges latérales, mais d'un faible moment dipolaire; ceci se traduit par une moindre sensibilité à l'égard des ions salins.

Précipitation des protéines du poisson: pourcentage de la saturation en sulfate d'ammonium.

Tropomyosine	50–66
Myosine	35–48
Actine	10–20
Actomyosine	28–38

Résultats de l'électrophorèse

La myosine pure donne un sommet élargi qui peut indiquer la présence de quelque hétérogénéité. Le myogène donne 7 constituants par l'électrophorèse de Tiselius. Chaque espèce de poissons donne une disposition différente. L'électrophorèse dans le gel d'empois d'amidon donne 12 constituants au pH 7,5.

Résultats de l'ultra-centrifugation

L'actomyosine et la tropomyosine donnent toutes deux un sommet aigu. La myosine n'est pas homogène. Le myogène donne quatre constituants.

Protéines cristallisées du poisson

Protéines du myogène, myoglobine et tropomyosine.

Dans le muscle blanc, le métabolisme glycogénique prédomine; dans le muscle rouge (*Musculus lateralis superficialis trunci*), c'est probablement le cycle de l'acide citrique qui prévaut.

Le muscle rouge (par exemple, chez le thon) semble être un muscle passif avec un haut métabolisme de l'oxygène. Le muscle blanc est un muscle actif avec un faible apport d'oxygène.

PROTEINAS EN EL TEJIDO MUSCULAR DEL PESCADO

(1) Proteínas de las fibrillas musculares, tropomiosina, actina, miosina y actomiosina: 65% de las proteínas del tejido muscular del pescado (40% en los mamíferos).
(2) Proteínas de citoplasma (enzimas en el metabolismo muscular), globulina x, miógeno, mioglobina: 26–30% de las proteínas del tejido muscular del pescado (35–40% en los mamíferos).
(3) Proteínas del tejido conjunctivo, estromaproteínas (colágeno): 3% del tejido muscular de los teleósteos; 10% de los elasmobranquios; (17% de los mamíferos).
Grupo 1: Extractable con una solución de sal neutra de gran fuerza iónica $> 0,5$.
Grupo 2: Extractable con una solución de sal neutra de poca fuerza iónica $\leqslant 0,15$.
Grupo 3: No extractable con solución de sal neutra, tampoco en ácidos diluidos y álcalis.

El Grupo 1 tiene gran energía reticular cristalina y un gran momento dipolar, lo que produce una gran sensibilidad con respecto a los iones salinos.

El Grupo 2 es rico en cadenas laterales cargadas, pero tiene un pequeño momento dipolar, lo que produce una menor sensibilidad respecto a los iones salinos.

Precipitación de proteínas de pescado: porcentage de saturación del sulfato amónico.

Tropomiosina	50–66
Miosina	35–48
Actina	10–20
Actomiosina	28–38

Resultado de la electroforesis

La actomiosina pura y la actina pura dan un máximo agudo. La miosina pura da un máximo más ancho, lo que puede indicar la presencia de alguna heterogeneidad. El miógen da 7 componentes por electroforesis de Tiselius. Cada especie de pescado da una disposición diferente. La electroforesis en gel de almidón da 12 constituyentes pH 7,5.

Resultados por ultracentrifugación

La actomiosina y la tropomiosina dan un máximo agudo. La miosina no es homogénea. El miógeno da cuatro constituyentes.

Proteínas cristalizadas de pescado

Proteínas de miógeno, mioglobina y tropomiosina.

En el músculo blanco, predomina el metabolismo glicogénico; en el músculo rojo (*Musculus lateralis superficialis trunci*) probablemente prevalece el ciclo del ácido cítrico.

El músculo rojo (por ejemplo, en el atún) parece ser pasivo, con un alto metabolismo del oxígeno. El músculo blanco es activo con una débil aportación de oxígeno. Puede existir una cooperación metabólica, pero ésta no es común en fisiología.

THE muscles consist of fibre cells, in which lie bundles of chain-molecules; and round the fibrils is a clear solution, called sarcoplasma. Muscle cells are surrounded by membranes (1).

Along the lateral line of the fish, there is a red superficial muscular region underneath the skin, called the red muscle or *Musculus lateralis superficialis trunci*, which differs in constitution from the rest of the muscle tissue (2, 3).

The proteins of muscle may be classified thus:

(1) *Tropomyosin*, *actin*, *myosin* and *actomyosin* which are the proteins that give the muscle its power of contraction. These represent about 65 per cent of the muscle proteins of fishes (against only 40 per cent of muscle proteins in mammals). They are extractable with a salt solution of high ionic strength ($> 0,5$).

(2) *Myogen* is found dissolved in the sarcoplasma, and *globulin x* seems to come chiefly from the mitochondria. These proteins constitute the enzymes of the muscle metabolism. They compose 26–30 per cent of the protein in fish muscle, in nearly equal amounts (whereas in mammals there are 35–40 per cent). Both these proteins are extractable at low ionic strength ($< 0{\cdot}15$). But according to its name globulin x is insoluble in water when the conductive power decreases to 10^{-4}, whereas myogen is an albumin and soluble in water.

(3) The *stroma proteins*, which form the connective tissue of the muscle. They amount only to 3 per cent in teleost muscle, and 10 per cent in elasmobranch muscle (against 17 per cent in mammals) (7). They consist of the glue-forming collagen (6), which is not soluble in neutral salt solution, nor in diluted acids and alkalies.

Preparation of the fish proteins

The actomyosin is prepared by extracting a muscle pulp by means of a bicarbonate-buffered 0·5 mol potassium-chloride solution, pH 7·5 at 0°C. The remnants are spinned down, and the actomyosin is precipitated by diluting it to an ionic strength below 0·35, and the precipitate is washed with water. Then it is dissolved in a salt solution. The whole process is repeated several times to get a clean actomyosin solution.

Clean myosin is particularly intricate to make from muscle of fish.

The process is almost the same as with actomyosin; but to the extraction solution is added adenosine-triphosphate (ATP), to keep actomyosin dissociated in actin and myosin, and versen (also called titriplex), to bind earth alkali iones. In this way, the ATP-ase effect of myosin is inhibited.

The actomyosin is removed from the myosin solution by dialysing it against a buffer solution with ionic strength 0·25 and pH 7·1. In this way the actomyosin falls out (28, 33).

Actin is isolated in the following way: the ground fish fillets are washed a few times with pure alcohol, and then several times with ether. From the dried fibre mass the actin is then extracted with a sodium-chloride solution pH 7·3 and ionic strength = 1·0. The actin is then purified by centrifugation (11, 26).

The proteins of sarcoplasma are obtained by extraction of the minced fish muscle with cold water. By dialysing the solution against water for 64 hours, the globulin x group is precipitated. This denaturation is characteristic for this group, but makes investigation difficult.

The myogen group contains nearly 50 enzymes. By cautious addition of $(NH_4)_2SO_4$ with a little sodium-phosphate, or with alcohol, this group is divided into a series of fractions with different degrees of solubility. These fractions are further separated by electrophoresis, ultracentrifugation and crystallization.

Together with the myogen proteins is found the red protein, myoglobin. This can be purified by 0·5 m. basic lead acetate at 30°C and precipitated at 80–95 per cent saturation of ammonium sulphate (12, 13, 14).

As the electrophoretic pattern shows, the myoglobin represents the major part of the red pigment of the red and the bright muscle in tuna (*Thunnus thynnus*). It forms one single peak in tuna and two peaks in carp (12). Its contents can be determined by the alkaline haematine method. The amount of myoglobin in the bright muscle varies from 0·02 to 0·08 units of Klegg and King haemoglobin standard, in the dark muscle about 0·14. There is no relation between the myoglobin composition and the size of the tuna (15, 16).

Physical and chemical properties of fish proteins

At the iso-electric point (pH 4–5·5) where the proteins are electrically neutral, they are least soluble and they can easily denaturate.

By the addition of a neutral salt-like sodiumchloride, the iso-electric point will be displaced to a lower pH.

In the alkaline region the addition of salt will increase the solubility of the proteins. This particularly concerns the myosin-groups, which is made up of proteins with great crystal lattice energy and a great dipole moment.

The myogen group, on the contrary, belongs to the water-soluble proteins, rich in charged groups, but with a small dipole moment (17).

The extractability of muscle proteins of cod increases from 13 per cent at pH 5 to 95 per cent at pH 6, with a salt solution of ionic strength 0·85 (2, 18).

The ability to swell and increase in hydration in the alkaline region can be explained by an increase in acid groups, particularly carboxyl groups, or by reduction in the number of basic groups in the protein.

Calcium-ions will reduce swelling. It may be explained by calcium-ions blockading the carboxyl groups, thus reducing the number of acid groups.

If we add sodium chloride to an acid fish protein solution, the salt has the opposite effect; it reduces the swelling and solubility of the proteins. This may be due to a "salting out" effect, i.e. the precipitating effect of salts which have common ions.

The salts which have the greatest swelling and solubilizing effect are mainly those with multivalent cations.

If one increases the salt concentration beyond a certain limit, the proteins are precipitated.

The farther away we are from the iso-electric point, the higher is the salt concentration which is needed. This effect is explained by the salt ions absorbing the polar molecules of the solution and displacing the protein molecules, so that these precipitate.

The salts with the highest precipitating effect are those with multivalent anions, but in many salts the saturation occurs at so low a concentration that precipitation is not possible.

The percentage saturation of ammonium sulphate for precipitation follows:

Myoglobin ab. pH 7 (tuna) . .	75–95 (2)
Myosin	35–48 (19, 2)
Tropomyosin at pH 5·2 (carp) . .	50–66 (2)
Actomyosin	28–38 (18)
Actin	10–20 (18)

Generally an increase of temperature enlarges the solubility of proteins in diluted solutions and enlarges the precipitation of proteins in more concentrated salt solutions.

The mobility of fish proteins is closely connected to what is said about the iso-electric point and charged groups.

To get a picture of the electrophoretic behaviour of the fish proteins, diagrams of the fish proteins at the range of pH 4–9 have been made (20).

The electrophoresis of fish proteins, extracted at high ionic strength, is difficult, particularly for smaller components, because of the viscosity of the solution.

At pH 7·4 there is a sharp peak of actomyosin.

Myosin gives a broader peak of a slightly lower velocity (21).

It has been shown that fish myosin aggregates more easily than rabbit myosin (41).

The myogen and globulin x group both show a rather corresponding electrophoretic velocity, and higher than rabbit (19, 22).

The electrophoretic pattern of each species of fishes differs so much that it may be used as a sort of "fingerprint" for the species (23, 24).

By means of electrophoresis in starchgel at pH 7·4 it has been possible to obtain better separation of the myogens. We can distinguish 12 gradients by this method, against 7 by means of electrophoresis in buffer solution or on paper. But this method is troublesome, and it is difficult to measure the area of the peaks exactly (25).

By electrophoresis the proteins are separated and characterized; but as the composition of the amino acids in the enzymes seems to change from one species of fishes to another, the method needs to be supplied with enzymologic measurements to reveal the laws and relationship of the species of fishes.

Ultracentrifugal studies

By means of ultracentrifuge one has measured the sedimentation of fish proteins. One gets an idea of the molweight and the structure, and it also helps in the control of the purity of protein preparates.

It has been difficult to obtain a fish myosin with one sharp peak (21, 26). This may have the same reason as mentioned for electrophoresis.

The ultracentrifuge diagram of the great myogen group gives only 3–4 peaks; but in combination with fractionation with ammonium sulphate and following electrophoresis, one finds that generally the myogen fractions precipitating by increasing salt saturation tend to increase in electrophoretic mobility and to decrease in sedimentation velocities; but there are several exceptions (22).

Viscosity

The measurements of viscosity by means of an Ostwald-viscosimeter have been used to follow the formation of actomyosin from actin and myosin, and to study the dissociation of actomyosin by addition of adenosine-triphosphate.

The increase in viscosity by formation of actomyosin seems higher in fish than in mammals; and because the number of free sulphydryl groups in myosin is responsible for the increase of viscosity, this gives some small indication that myosin of fish has more free sulphydryl groups than in mammals. Unfortunately, the values vary in the various preparations (2, 26, 27).

The intrinsic viscosity of fish proteins is as follows:

Actomyosin	5·0–5·4	(in rabbits 3–5)
Myosin	2·0	(in rabbits 2·2)
G-actin	0·075	(in rabbits 0·20)

The measurements of viscosity are limited to a short range of concentration near 0·2 per cent actomyosin. At too high a concentration the thixotropy interferes; at too low a concentration one gets turbulence in the capillary and disturbances by agglutination (28).

Crystallization

It has been possible to crystallize several myogen proteins from carp, plaice and cod after fractional precipitation with $(NH_4)_2SO_4$ or with alcohol (25), further to crystallize myoglobin from tuna and carp, and also nucleotropomyosin. The proteins have proved to be homogeneous by electrophoresis and ultracentrifugation (2, 22, 29).

Spectrophotometric examination

In oxymyoglobin of tuna three maxima are found in the visible region, one at about 415 $m\mu$, and two smaller ones at 540 and 575. This corresponds to that of mammals (2, 9).

The ultraviolet absorption of carp nucleotropomyosin has shown 10–20 per cent ribonucleic acid (2). The ultraviolet spectrum of a myogen fraction of plaice and carp which was precipitated at 90–100 per cent $(NH_4)_2SO_4$ showed that this protein contained no tyrosin and tryptophan, but nearly 17 per cent phenylalanine (22, 29).

Influence of fatty acids on proteins

It has been observed that the fatty acids not only influence juiciness, tenderness and aroma, but the fatty acid anions also stabilize the protein structure of fish muscle, prevent the breaking of hydrogen bridges, and make the proteins more stable against heat as well as against freeze denaturation. The maximal effect is considered to be obtained by 8 moles fatty acids with 12 carbon atoms per cent mol protein (30, 31, 32).

Metabolism of the muscle

In the relaxed muscle, myosin forms a stable complex with adenosine-triphosphate (ATP) and potassium, calcium and magnesium ions.

By the contraction of the muscle, myosin, by means of its ATP-ase property, splits off a phosphate group from ATP, and the great energy which is hereby set free is used by myosin to form a contracted actomyosin compound.

There are in the muscle two systems producing ATP, the first going out from lipids, the citric acid cycle, the second is the glycolytic system.

In the original system, which we found in the smooth muscle and in undifferentiated muscles of foetus, the enzymes of the citric acid cycle dominate compared to glycolysis (34).

At present this phenomenon is being studied to see if this is to some extent the case with the red muscle with its low muscle activity.

In the skeletal muscle, like the ordinary white muscle of fish, there are nearly ten times more glycolytic enzymes than enzymes of the citric acid cycle (34). Ordinarily the circulation of blood in a passive muscle is low (35), and consequently there is a low metabolism.

However, the red muscle is rich in blood capillaries (36, 37). It has a high content of myoglobin and probably of the enzymes of the cytochromic system, properties which distinguish an active tissue (38, 39, 40). Notable is also the fact that it lies parallel to the white muscle with its low supply of oxygen (2).

It is tempting to say that there must be some sort of metabolic co-operation between the red and the white muscle (3).

Time will show if such a differentiated partition of functions, which is exceptional in physiology, is indeed possible.

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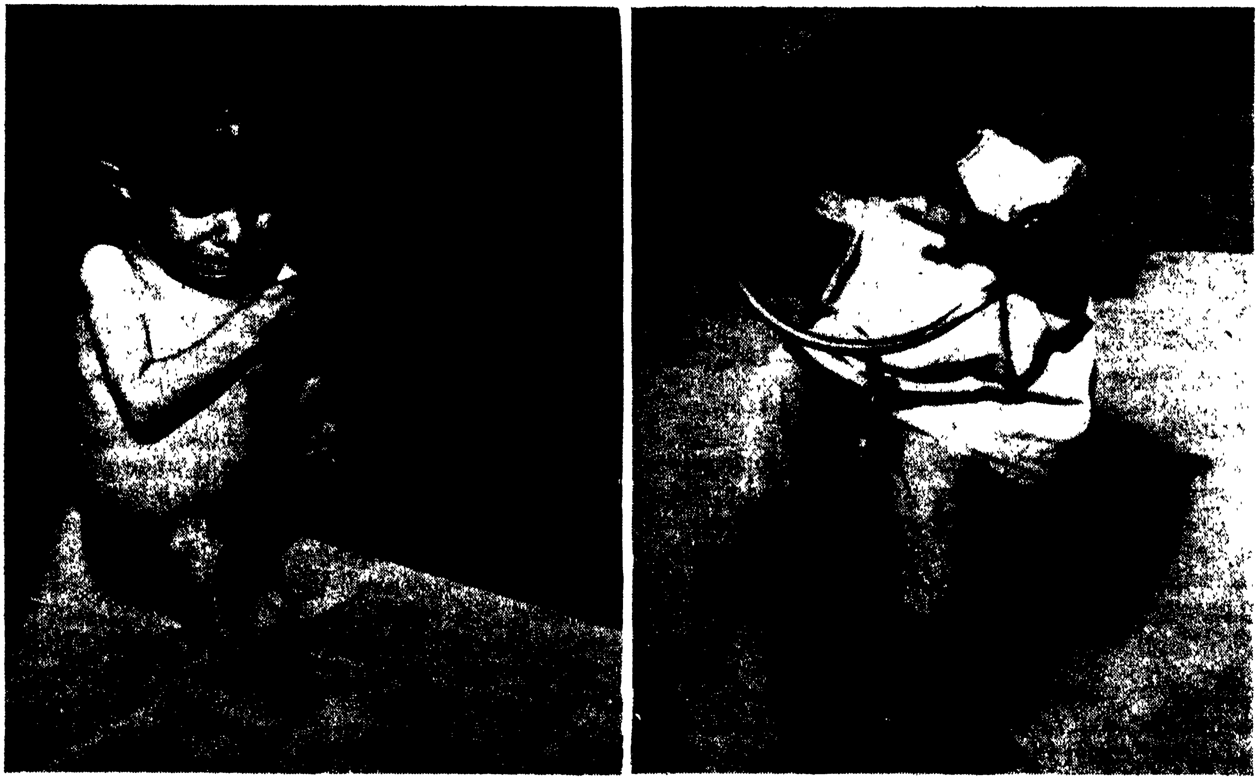

It will interest scientists (and other readers) to see the importance in practical human feeding of proteins in fish. Believe it or not, these pictures are of the same girl. Her name is Sakeneh. She weighed only 6 kilograms when the picture on the left was taken and showed every evidence of malnutrition caused mainly by deficiency in protein. After a year's treatment in which she gained up to 600 grams in weight a month, she is pictured happy and laughing, on the right. Pictures from Public Health Department, Iran, through FAO show the work of the Children's Emergency Fund.

THE AMINO ACID COMPOSITION OF FISH MUSCLE PROTEINS

by

G. HAMOIR

Present evidence points to the existence of a fundamental amino-acid plan for the constitution of the proteins of the myofibril: myosin, actin and tropomyosin, of the lower as well as the higher vertebrates.

The opposite, however, occurs in the case of the proteins dissolved in the sarcoplasm (myogen). The electrophoretic patterns of the myogens of fish are characteristic of each species; they differ from those of warm-blooded vertebrates by a common higher average mobility. On the other hand, the myogens of fish contain proteins having rates of sedimentation of 1·3–1·5, 4·5–5·0 and 6·5–7·2 S. The first group is absent in the case of warm-blooded vertebrates myogens. It amounts to as much as about 50 per cent in carp myogen. When isolated and subjected to electrophoresis at neutral pH, this fraction resolves in the case of the carp into three peaks. Two components migrating at the levels of the second and third peaks have been isolated. The study of their properties has shown that their molecular weight is around 14,000, and their amino-acid compositions extremely abnormal. A major component, having a rate of sedimentation of 5 S and a high electrophoretic mobility, has also been isolated from carp myogen. A corresponding component does not seem to exist in warm-blooded vertebrates. Investigations carried out on carp aldolase and carp glyceraldehyde deshydrogenase have shown that their electrophoretic mobilities are low at pH 7, and similar to (if not identical with) those of the corresponding rabbit muscle enzymes.

These results suggest that, as against the myogen of warm-blooded animals which is usually assumed to be made up mainly of glycolytic enzymes, the myogen of cold-blooded vertebrates contains three distinct groups of proteins: the first one, not observed in the case of other vertebrates and containing proteins of small molecular weight and very unusual amino-acid composition; a second one, with a sedimentation rate of 5 S and a fairly high electrophoretic mobility; and a third one corresponding to glycolytic enzymes. Some components of the fish myogen may form a protein reserve, or may have some biological function not occurring in warm-blooded muscle which has still to be defined.

LA COMPOSITION EN AMINO-ACIDES DES PROTEINES DU MUSCLE DE POISSON

Les protéines intervenant dans la composition des myofibrilles (myosine, actine, tropomyosine) ont la même composition en acides aminés dans le cas de tous les vertébrés. Par contre, les protéines du sarcoplasme formant le myogène diffèrent à ce point de vue suivant leur origine. Les diagrammes électrophorétiques de myogènes de vertébrés à sang-froid diffèrent d'une espèce à l'autre, et se distinguent de ceux vertébrés à sang-chaud par une mobilité moyenne plus élevée. Les myogènes de poissons se scindent à l'ultracentrifugation en trois groupes de protéines de vitesses de sédimentation 1,3–1,5, 4,5–5,0, et 6,5–7,2 S. Le premier groupe n'existe pas dans les myogènes des vertébrés à sang-chaud. Il représente chez la carpe environ 50% du myogène. Lorsqu'on l'isole de muscles de carpe et l'analyse par électrophorèse à pH neutre, il se scinde en trois gradients. Des composants migrant au niveau du deuxième et du troisième gradient ont été isolés. L'étude de leurs propriétés ont montré que leurs poids moléculaires est d'environ 14.000 et que leurs compositions en acides aminés sont extrêmement anormales. Un composant important de vitesse 5 S et de mobilité électrophorétique élevée a aussi été isolé du myogène de carpe. Il ne paraît pas représenté dans le myogène des vertébrés supérieurs. Des recherches relatives à l'aldolase de carpe et à la glycéraldéhyde déshydrogénase de carpe ont montré que leurs mobilités électrophorétiques sont peu élevées à pH 7, et semblables (sinon identiques) à celles des enzymes musculaires correspondants du lapin.

Ces résultats suggèrent que le myogène de poisson contient trois groupes de protéines: le premier, qu'on n'observe pas chez les autres vertébrés et qui contient des protéines de poids moléculaire très faible et de compositions en acides aminés très anormales; le deuxième, de vitesse de sédimentation de 5 S et de mobilité électrophorétique élevée; et le troisième correspondant aux enzymes glycolytiques. Il est possible que certains constituants du myogène de poisson forment une réserve protéique ou assurent une fonction biologique n'existant pas dans le cas des vertébrés supérieurs qui reste encore à identifier.

LA COMPOSICION EN AMINOACIDOS DE LAS PROTEINAS DEL TEJIDO MUSCULAR DEL PESCADO

Las pruebas actuales señalan que las proteínas, que intervienen en la composición de miofibrillas (miosina, actina, tropomiosina), tienen la misma composición en aminoácidos en los vertebrados inferiores y superiores.

Ocurre lo contrario, sin embargo, en el caso de las proteínas del sarcoplasma que forman el miógeno. Los diagramas electroforéticos de miógenos de pescado son diferentes en cada especie, y se distinguen de los vertebrados de sangre caliente por una movilidad media más elevada. Por otra parte, los miógenos de pescado contienen proteínas con velocidades de sedimentación de 1,3 a 1,5; 4,5 a 5,0; y 6,5 a 7,2 S. El primer grupo no existe en los miógenos de los vertebrados de sangre caliente. Representa aproximadamente el 50% del miógeno de la carpa. Cuando se aísla y se somete a electroforesis a pH neutro, esta fracción se subdivide en tres gradientes. Se han aislado dos componentes migratorios a los niveles del segundo y tercer gradientes. El estudio de sus propiedades ha mostrado que sus pesos moleculares son de 14.000 aproximadamente, y que sus composiziones en aminoácidos son extremadamente anormales. Un componente importante, con una velocidad de sedimentación de 5 S y una movilidad electroforética elevada, se aisló también del miógeno de la carpa. Este componente no parece existir en los vertebrados de sangre caliente. Las investigaciones realizadas sobre la aldolasa de carpa y el gliceraldehído deshidrogenasa de carpa han mostrado que sus movilidades electroforéticas son poco elevadas a pH 7, y parecidas (si no idénticas) a las de los enzimas de músculo de conejo.

Estos resultados sugieren que, al contrario del miógeno de animales de sangre caliente que se supone está formado principalmente de enzimas glicolíticas, el miógeno de los vertebrados de pescado contiene tres grupos distintos de proteínas: el primero, que no se observa en los demás vertebrados, que contiene proteínas de peso molecular pequeño y una composición en aminoácidos muy anormal; el segundo, con una velocidad de sedimentación de 5 S y una elevada movilidad electroforética; y el tercero, que corresponde a los enzimas glicolíticos. Es posible que algunos componentes del miógeno de pescado formen una reserva proteica o tengan alguna función biológica que no existe en el caso de los vertebrados superiores, que no se haya determinado todavía.

THE composition of myosins of different origins (rabbit, dog, ox, chicken, fish and lobster) was first investigated by Bailey (1). Their contents in four amino acids (cystine, methionine, tyrosine and tryptophan) were determined. The figures obtained with lobster and, even more, fish, were less reproducible and somewhat higher than the other ones. Similar results were found by Deas and Tarr (7) on longcod myosin.

The progress made recently by Connell (3) in the isolation of cod myosin and cod actin has made it possible to obtain better preparations enjoying a purity comparable with those of the corresponding rabbit proteins. The detailed amino acid analyses made on these proteins by Connell and Howgate (5) are therefore of great interest. Their results show that the discrepancies observed by Bailey (1) are due to the contamination of the fish myosin by actin. Cod myosin and cod actin have amino acid compositions which differ very little from the corresponding rabbit proteins. The same similarity is observed with tropomyosin: Kubo (17) has shown that the composition of haddock tropomyosin is very close to the one of rabbit tropomyosin. All these results point thus to the existence of a fundamental amino acid plan for the elaboration of the muscle structural proteins, i.e. the constituents of the myofibrils.

The opposite occurs in the case of the proteins dissolved in the sarcoplasm. The variability of fish myogens has first been suggested by electrophoretic and ultracentrifugal investigations. Muscle extracts made at low ionic strength of many different species of fish have been examined electrophoretically by Connell, Nikkilà and Linko, and by myself (13). The patterns obtained with lower vertebrates are very variable and characteristic of each species. They have in common, however, a higher mean mobility than the one of warm-blooded vertebrates (Fig. 1). Ultracentrifugal analyses have been made on carp (12), plaice (18) and cod (4). These patterns are more similar *inter se* than the electrophoretic ones: three peaks are observed, in each case having rates of sedimentation of 1·3–1·5, 4·5–5·0 and 6·5–7·2 S. The specific variations appear to be limited here to the proportions of these three peaks. In carp extracts, the slow peak is particularly large: it amounts to approximately 50 per cent of the proteins present (12, 16). This slow sedimenting peak is absent in the myogens of warm-blooded vertebrates. It apparently occurs only in fish muscle and in frog muscle (8). As the ultraviolet absorption of protein isolated from this fraction revealed a very peculiar amino acid composition (15), we have tried to isolate these slow sedimenting components from carp muscle extracts. It can be achieved fairly easily with a good yield by ammonium sulfate fractionation at neutral pH. The single slow ultracentrifugal peak obtained splits by electrophoresis at neutral pH into three peaks which correspond to the peaks I, IIa and IIc of Fig. 1. Two components have been isolated and crystallized: one corresponds to the peak IIa, and the other to the peak IIc or to part of it. The ultraviolet spectrum reveals in both cases a high content in phenylalanine and the absence of tyrosine and tryptophan. The molecular weight of the component IIa has been found to be 14,000 ± 500. The amino acid compositions of the two crystallized proteins have been determined with the Moore and Stein method and microbiologically (Table I). Tyrosine, tryptophan, proline and methionine are absent, and one residue of cysteine, arginine and histidine is found per 14,000 g. in both cases. The higher electrophoretic mobility of one protein at pH 7 is due to its higher content in aspartic acid (+11 residues per 14,000 g.) and its lower content in lysine (−5 residues per 14,000 g.). We have found with Jebsen (18) that a component sedimenting at the same rate, and having the same ultraviolet spectrum, occurs also in plaice myogen. These results suggest that the fraction sedimenting at a rate of 1·3–1·5 S corresponds to a family of proteins characteristic of cold-blooded vertebrates, of a molecular weight of about 14,000 and highly abnormal amino acid composition.

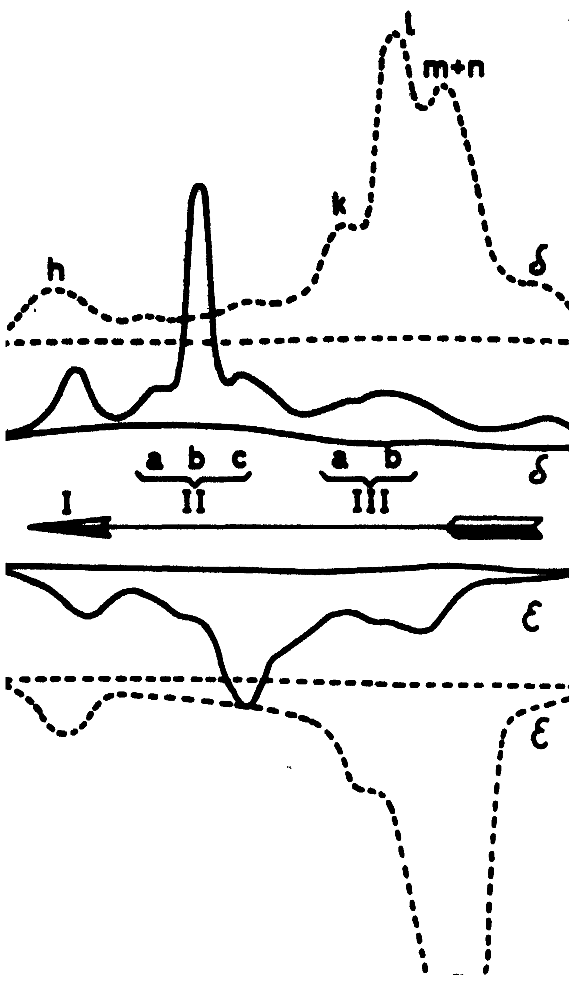

Fig. 1. Electrophoretic diagrams of carp myogen (———) and rabbit myogen (- - - - -) at I 0·15 and pH 7·3

The other half of the carp albumins has also been investigated. A major component sedimenting at a rate of 5 S has been isolated and crystallized (14). Its amino acid composition has been compared to those of several rabbit muscle proteins (Table II). This comparison does not at first sight reveal any peculiarity. On the other hand, enzymatic researches have been carried out in our laboratory in order to isolate carp aldolase (11) and carp glyceraldehyde dehydrogenase (19). Both of these

TABLE I

Amino acid composition in residues/14,000 g. protein

	Median electrophoretic peak (IIa)		*Slow Component (IIc)*
	Stein and Moore	*Microbiological*	*Stein and Moore*
Alanine	23	21	20–21
Glycine	9	?	10
Valine	5	5–6	5–6
Leucine	10	10	11
Isoleucine	4	7	5
Proline	0	0	0
Phenylalanine	11	10–12	13
Tyrosine	0	0	0
Tryptophan	—	—	—
Serine	6	—	4–5
Threonine	6	7	7
Cysteine	1	—	1
Methionine	0	0	0
Arginine	1	1	1
Histidine	1	1	1
Lysine	13	14	19
Aspartic Acid	19	17–18	7
Glutamic Acid	9	8	10
Amide N	9	—	10
Total	127	103	126

TABLE II

Amino acid compositions of carp and rabbit muscle proteins in g./100 g. (from Henrotte, 1960)

	Carp myogen I (Henrotte, 1960)	*Rabbit myogen (Bailey, 1937)*	*Rabbit aldolase (Velick and Ronzoni, 1948)*	*Rabbit glyceraldehyde phosphate deshydrogenase (Velick and Udenfriend, 1953)*	*Rabbit myosin (Bailey, 1948)*
Alanine	2·43		8·56	7·3	6·5
Arginine	6·38		6·33	5·2	7·36
Aspartic Acid	12·34		9·7	10·6	8·9
Glutamic Acid	12·82		11·40	5·7	22·1
Glycine	8·14		5·61	5·9	1·9
Histidine	4·07		4·21	5	3·41
Isoleucine	6·92		7·9		15·6
Leucine	9·81		11·5		
Methionine	3·21	2·8	1·17	2·7	3·4
Lysine	10·16		9·54	9·7	11·92
Phenylalanine	5·58		3·06	5·8	4·3
Proline	4·36		5·71	3·4	1·9
Threonine	5·61		7·47	5·2	5·1
Tyrosine	3·43	4·21	5·31	4·6	3·4
Valine	6·7		7·4	9·2	2·6
Cystine		1·96	2·24		2·8
Tryptophan		1·51	2·31	2·1	0·8
Serine			7·3	4·4	4·33
Total	101·96		115·6		

enzymes are migrating at the level of peak III (probably of peak IIIb), while rabbit aldolase is migrating at the level of *l* (9, 10, 20) and rabbit glyceraldehyde dehydrogenase slightly more slowly (6) (cf. Fig. 1). This similarity is remarkable in view of the much larger mean electrophoretic mobility of the fish myogens. The ultracentrifugal behaviours of carp and rabbit glyceraldehyde deshydrogenases are also very similar, if not identical (19). Although a larger number of enzymes should be examined before final conclusion be reached, it seems from the present evidence that the glycolytic enzymes of fish myogen correspond only to the slow electrophoretic peak III.

It is usually assumed that the myogen of warm-blooded animals is made mainly of glycolytic enzymes (2). Our results suggest that this view is incorrect in the case of the myogens of cold-blooded vertebrates. It seems that three different groups of proteins should be distinguished in this case: a first one, not observed in the case of other vertebrates containing proteins of small molecular weight and very abnormal amino acid composition; a second one, of a rate of sedimentation of 5 S and fairly high electrophoretic mobility (component IIb of Fig. 1); and a third one corresponding to the glycolytic enzymes. Some components of fish myogen may form a protein reserve, or may have another biological function which has still to be defined. In any case the occurrence in fish muscle of proteins, which are devoid of methionine and tryptophan, in perceptible quantities varying from one species to the other, should be taken into account when assessing the nutritive value of this food.

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EFFECTS OF BIOLOGICAL FACTORS (SEX, SEASONAL RACES, SPAWNING MIGRATIONS) ON FAT, PROTEIN AND WATER, THEIR DISTRIBUTION IN SEA-TROUT

by

J. T. KUKUCZ

The effects of some biological factors (sex, spawning migrations, seasonal races) on some components of edible parts of fish and its nutritional value were investigated in 1958–59. Chemical composition of many species of fish has been the subject of numerous investigations; but the relationship between the biological stages of fish and such components as fat, water and protein are not sufficiently known in the majority of species.

The object of studies was the sea-trout (*Salmo trutta* L.) from the Vistula River, known on the international markets under the name Vistula Salmon. There exist two populations within this species: (1) the winter population, which undertakes a 1,000-km. long migration and spawns in tributaries of the upper Vistula one year after entering the river, and (2) the summer population, which spawns in the tributaries of the lower part of the main river in the year of entering.

The fat, water and protein content of specimens belonging to winter and summer populations caught in the year cycle 1958–59 was examined

The winter population shows an adaptation to the conditions of long spawning migration in the form of enormous accumulation of stock material in the body of the fish. This influences the technological properties of the fish.

It has been stated that the fat content of specimens of the winter population was on the average twice as high (fem. 17·40 per cent, male 13·82 per cent) as that of the summer population (fem. 7·91 per cent, male 6·86 per cent). The females of both seasonal populations have a slightly greater amount of fat than the males.

The following distribution of fat has been found:

The accumulation of fat is considerably greater in the ventral than in the dorsal part of the body. There is less fat in the posterior part of the ventral lobes than in the anterior part; conversely, the fat content increases in the dorsal part towards the tail. A distinctly smaller amount of fat is accumulated in the tail itself. The statements concerning the distribution of fat in the different parts of the body might be important from the technological point of view.

The comparison of fat content in winter populations at the beginning of the spawning migration (fem. 17·04 per cent, male 13·82 per cent) with the content of fat in spent fish at the end of the migration (fem. 4·05 per cent, male 2·85 per cent) shows that sea-trout lose about 80–85 per cent of their fat supply during their spawning migration.

The water content is in inverse proportion to the amount of fat.

The differences in protein content are smaller (fem. 20·26 per cent, male 20·53 per cent in summer population; and fem. 21.31 per cent, male 21·76 per cent in winter population).

The protein content decreased considerably during spawning migration (about 15 per cent: at the beginning of the migration, fem. 20·26 per cent, male 20·53 per cent; at the end of the migration, fem. 16·62 per cent male 17·30 per cent).

Besides the changes in the amount of single components as mentioned above, the whole weight and the condition factor in spawned fishes decrease considerably.

EFFETS DES FACTEURS BIOLOGIQUES (SEXE, VARIETES SAISONNIERES, MIGRATION DE REPRODUCTION) SUR LES GRAISSES, LES PROTEINES ET L'EAU ET SUR LEUR DISTRIBUTION CHEZ LA TRUITE DE MER (*SALMO TRUTTA* L.)

Les effets de quelques facteurs biologiques (sexe, migrations de reproduction, variétés saisonnières) sur quelques composants des parties comestibles du poisson et sur sa valeur nutritive ont été étudiés en 1958–59. La composition chimique de nombreuses espèces de poisson a été le sujet de bien des études; mais les relations entre les étapes biologiques du poisson et des composants tels que les graisses, l'eau ou les protéines ne sont pas suffisamment connues dans la majorité des espèces.

L'objet de ces études a été la truite de mer (*Salmo trutta* L.) de la Vistule, connue sur les marchés internationaux sous le titre de saumon de la Vistule. Il existe deux populations dans cette espèce: (1) la population d'hiver, entreprenant une migration de 1.000 km. et se reproduisant dans les affluents de la Vistule supérieure un an après son entrée dans le fleuve; et (2) la population d'été, se reproduisant dans les tributaires du cours inférieur du fleuve principal dans l'année de son entrée.

On a examiné les graisses, l'eau et la teneur en protéines sur des spécimens appartenant aux populations d'hiver et d'été, capturées au cours du cycle annuel 1958–59.

La population d'hiver montre une adaptation aux conditions d'une longue migration de reproduction sous la forme d'une accumulation énorme de réserves dans le corps du poisson. Ceci influence les qualités industrielles du poisson.

On a établi que la teneur en graisse des spécimens de la population d'hiver était en moyenne deux fois plus élevée (fem. 7,91 %, mâles 6,86 %). Les femelles des deux populations présentaient une quantité de graisse légèrement supérieure à celle des mâles.

On a trouvé la répartition suivante de la graisse:

L'accumulation de la graisse est beaucoup plus élevée dans la partie ventrale du corps que dans sa partie dorsale. Il y a moins de graisses dans la partie postérieure des lobes abdominaux que dans leur partie antérieure; en revanche, la teneur en graisse augmente dans la zone dorsale vers la queue. La quantité de graisse accumulée dans la queue elle-même est nettement plus faible. Les données concernant la distribution de la graisse dans les différentes parties du corps peuvent être importantes du point de vue industriel.

La comparaison de la teneur en graisse chez les populations d'hiver au début de leur migration de reproduction (fem. 17,04 %, mâles 13,82 %) avec celle du poisson épuisé au terme de sa migration (fem. 4,05 %, mâles 2,85 %) permet de dire que la truite de mer perd approximativement 80 à 85 % de sa réserve de graisse durant cette migration.

La teneur en eau est en relation opposée avec la quantité de graisse.

Les différences dans la teneur en protéines étaient plus faibles (fem. 20,26 %, mâles 20,53 % dans la population d'été; fem. 21,31 %, mâles 21,76 % dans la population d'hiver).

La teneur en protéines décroit d'une façon considérable durant la migration de reproduction (de 15 % environ: au commencement de la migration, fem. 20,26 %, mâles 20,53 %; à la fin de la migration, fem. 16,62 %, mâles 17,30 %).

Parallèlement à ces changements dans le montant des composants simples qu'on vient d'indiquer, le poids total et le facteur de condition (facteur de l'état physiologique) dans le poisson en reproduction diminuent d'une façon considérable.

EFECTOS DE FACTORES BIOLOGICOS (SEXO, VARIACIONES ESTACIONALES Y EMIGRACIONES DE DESOVE) EN EL CONTENIDO Y DISTRIBUCION DE GRASA, PROTEINA Y AGUA EN LA TRUCHA COMUN O DE MAR (*SALMO TRUTTA* L.)

En 1958–59 se investigaron los efectos que factores biológicos (como sexo, variaciones estacionales y emigraciones de desove) tienen en algunos componentes de las partes comestibles del pescado y su valor nutritivo. La composición química de muchas especies de peces ha sido objeto de numerosas investigaciones; pero la relación entre las fases biológicas y componentes como la grasa, agua y proteína no se conocen lo suficiente en la mayoría de las especies.

El objeto del estudio fue la trucha común o de mar (*Salmo trutta* L.) del río Vístula, conocida en el mercado internacional con el nombre de salmón del Vístula. Dentro de esta especie existen dos poblaciones: (1) la de invierno, que realiza viajes de 1.000 km. y desova en los afluentes del alto Vístula un año después de entrar en el río; y (2) la de verano, que desova en los afluentes del bajo Vístula el mismo año que entra.

Se determinó el contenido de agua, grasa y proteína de ejemplares de ambas poblaciones pescados en la campaña 1958–59.

En la población de invierno se acusa una adaptación a las condiciones de la larga emigración de desove, acumulándose en el cuerpo una enorme cantidad de grasa que influye en la industrialización del pescado.

Se ha demostrado que el contenido de grasa en ejemplares de la población de invierno es, por término medio, dos veces mayor (hembras, 17,04%; machos, 13,82%) que en los de la población de verano (hembras, 7,91%; machos, 6,86%). Se observará que la hembra de ambas poblaciones contiene más grasa que el macho.

La grasa está distribuida como sigue:

La acumulación es mucho mayor en la parte ventral que en la dorsal. Hay menos en la parte posterior de los lóbulos ventrales que en la anterior. Por el contrario, en la parte dorsal aumenta hacia la cola, pero en esta misma hay una cantidad sensiblemente menor. Las determinaciones del contenido en diferentes partes del cuerpo puede tener importancia bajo el punto de vista industrial.

La comparación del contenido de grasa en las poblaciones de invierno al comienzo de la emigración de desove (17,04% en las hembras; 13,82% en los machos) y al fin (4,05% en las hembras; 2,85% en los machos) permite manifestar que la trucha pierde del 80 al 85% de la grasa durante tal emigración.

El contenido de agua está en proporción inversa al de grasa.

Las diferencias en el contenido proteínico son menores: 20,26% en las hembras y 20,53% en los machos de la población de verano; y 21,51% en las hembras y 21,76% en los machos de la población de invierno.

El contenido proteínico disminuye considerablemente durante la emigración de desove (15% aprox.); al comienzo el de las hembras es de 20,26% y el de los machos de 20,53% y al terminar es de 16,62% en las hembras y de 17,30% en los machos.

Además de los cambios en la cantidad de los componentes individuales mencionados, el peso y estado fisiológico de los peces que han desovado disminuyen considerablemente.

SUR LA PRESENCE NATURELLE DE FORMALDEHYDE DANS LES PRODUITS ALIMENTAIRES MARINS

by

F. SOUDAN

La présence de formol a été signalée dans le poisson frais et dans le poisson salé il y a une trentaine d'années, mais ce fait est resté peu connu. Aussi, des chimistes peuvent-ils conclure parfois à l'addition de formol dans des produits qui n'en ont jamais reçu.

Nous avons recherché le formol dans les produits préparés à partir d'animaux marins, et montré que sa présence était générale dans ceux contenant de l'oxyde de triméthylamine. L'oxyde de triméthylamine se scinde en formol et diméthylamine suivant une réaction d'équilibre plus connue dans le sens: aldéhyde + amine → aldimine.

A température ambiante, l'équilibre comporte seulement 3 pour mille de formol libre; mais dans un milieu apte à capter l'un des constituants, la réaction se poursuit au-delà de l'équilibre normal. C'est ainsi que la distillation d'oxyde de triméthylamine en présence d'un acide fort, qui fixe la base, libère plus de 80% du formol qui était combiné dans l'oxyde initial. Une telle réaction se produit pendant la recherche du formol dans les animaux marins, si l'oxyde n'a pas été mis hors de cause au préalable; un moyen commode consiste à le réduire en triméthylamine par le chlorure de titane $TiCl_3$.

Dans les muscles de poissons ou de crustacés, la scission de l'oxyde de triméthylamine se poursuit spontanément grâce aux nombreux radicaux auxquels le formol peut se combiner, parmi lesquels notamment les radicaux—NH_2 libres de protéines. Théoriquement la réaction pourrait continuer jusqu'à ce que le formol soit uniformément réparti entre tous les radicaux, ce qui aboutirait à une décomposition presque totale de l'oxyde de triméthylamine. En fait, elle ne parvient pas jusqu'à ce terme; mais elle produit néanmoins des quantités de formol qui dépassent parfois celles qui pourraient être additionées comme antiseptique sous forme d'hexaméthylènetétramine. Nous avons trouvé dans divers produits préparés (certains par nos soins) les teneurs en formol suivantes exprimées en mg. (Tableau I).

Plusieurs résultats surprennent: ceux relatifs aux harengs saurs paraissent bas, compte tenu de l'apport de formol de la fumée; ceux de la morue salée et des conserves de crevettes du Maroc paraissent extraordinairement élevés, comparés par exemple à ceux des anchois salés et des conserves de crevettes norvégiennes.

Le taux de formol semble avoir effectivement peu de rapport avec le degré de fumage des harengs saurs apprécié organoleptiquement ou par le dosage des phénols.

Quant aux taux élevés trouvés dans la morue salée et dans les crevettes marocaines, ils s'expliquent par le fait que ces produits sont ordinairement traités l'un au bisulfite de sodium pour le blanchir, l'autre au sulfite de sodium pour éviter le noircissement enzymatique, alors que les anchois salés ou les crevettes norvégiennes ne sont pas traités. L'ion sulfureux, se combinant instantanément au radical aldehyde, active la scission de l'oxyde de triméthylamine; le dérivé bisulfitique formé se décompose avec libération de formol au moment du dosage en milieu acide. Les teneurs en formol et en anhydride sulfureux sont en corrélation étroite surtout dans la morue salée où les échanges ultérieurs avec le milieu sont pratiquement nuls.

L'étude statistique des résultats obtenus sur une soixantaine d'échantillons de morue montre que le formol provient bien de l'oxyde de triméthylamine et non d'une addition extérieure.

En conclusion, il apparaît que le formol se forme naturellement dans les préparations de poissons ou de crustacés. Le taux de formol peut devenir élevé après un traitement tel que le sulfitage; ceci doit être accepté comme une conséquence normale par les règlements d'hygiène alimentaire qui admettent le sulfitage.

THE NATURAL FORMOL CONTENT IN FISHERIES PRODUCTS

The presence of formol in fresh and salted fish was reported some 30 years ago, although little was known about this and chemists sometimes drew the conclusion that formol had been added to the products when such was not the case.

We tested for formol in products prepared from marine animals, and proved that it generally occurred in those containing trimethylamine oxide. This oxide divides into formol and dimethylamine by a balanced reaction which is more familiar to us in the opposite direction, that is aldehyde + amine → aldimine.

At ambient temperature in this reaction there are only three parts per thousand of free formol; but where one of these elements reacts with other elements in a different environment, the reaction may go beyond the normal point of balance. For instance, the distillation of the oxide of trimethylamine by a strong acid which captures the base liberates over 80 per cent of the formol initially found in the oxide. This reaction occurs when we test for formol in marine animals, unless the oxide has been eliminated first; a convenient method is to reduce it to trimethylamine by titanium-trichloride.

In the muscles of fish and crustaceans, the oxide of trimethylamine continues to break down spontaneously, because of the many radicals with which the formol can combine, including especially free NH_2 groups of proteins. Theoretically this reaction could continue until the formol is divided evenly among all the radicals, which would lead to an almost total decomposition of the oxide of trimethylamine. Actually this point is not reached, although more formol is produced than would be added as an antiseptic in the form of hexamethylenetetramine. We found in several prepared products, some of which we cured ourselves, the quantities of formol (in milligrams) shown in Table 1.

Several of our findings were surprising. The figures for red herring seem low, considering the formol produced during its smoking; those for salted cod and canned Moroccan shrimp seem exceptionally high as compared, for instance, with those for salted anchovies and canned Norwegian shrimp.

Actually, the formol content seems to have little connection with either the degree of smoking of the herring, as judged from the taste and smell, or the proportion of phenols.

As regards the high figures for salted cod and Moroccan shrimp, these are explained by the fact that the first of these products is usually treated with sodium bisulphite to bleach it, and the second with sodium sulphite to prevent blackening due to enzyme action, while neither salted anchovies nor Norwegian shrimp are so treated. The sulphurous ion combining instantaneously with the aldehyde radical causes the breakdown of the trimethylamine oxide; the resulting bisulphite derivative decomposes, liberating formol when mixed in an acid medium. The formol and anhydride sulphurous acid content are closely related, particularly in the salted cod, in which there are practically no further chemical exchanges with the environment.

A statistical study of tests on about 60 samples of cod shows that the formol actually comes from the trimethylamine oxide, and has not been added.

In short, it appears that formol is produced naturally in preparations of fish or crustaceans. The amount of formol may become very high after treatment with, for instance, a sulphite or sulphurous acid. This must be accepted as normal in health regulations regarding food and drugs which permit this treatment.

SOBRE LA PRESENCIA DE FORMOL NATURAL EN LOS PRODUCTOS MARINOS

La presencia de formol en el pescado fresco y salado se señaló hace unos 30 años; pero como se sabía muy poco de esto, los químicos creyeron que se había añadido formol a los productos cuando no era tal el caso.

Nosotros investigamos el formol en los productos preparados a partir de animales marinos y demostramos que su presencia es general en los que contienen óxido de trimetilamina, que se transforma en formol y dimetilamina por una reacción de equilibrio más conocida en el sentido aldehído + amina → aldemina.

A la temperatura ambiente, en esta reacción solamente hay 3 partes por mil de formol libre; pero en un medio apto para captar uno de los constituyentes, la reacción puede sobrepasar el punto normal de equilibrio. Por ejemplo, la destilación del óxido de trimetilamina, en presencia de un ácido fuerte que fija la base, libera más de 80% de formol combinado en el óxido inicial. Esta reacción ocurre durante la investigación del formol en los animales marinos, a menos que el óxido se haya eliminado antes. Un método conveniente consiste en reducirlo a trimetilamina por el cloruro de titano.

En el tejido muscular de pescado y crustáceos, el óxido de trimetilamina continúa descomponiéndose espontáneamente, debido a los muchos radicales con los que se puede combinar el formol, entre los que están especialmente los radicales NH_2 libres de proteínas. Teóricamente esta reacción podría continuar hasta que el formol se repartiera uniformemente entre todos los radicales, lo que produciría una descomposición casi total del óxido de trimetilamina. En la práctica no se llega a esto, aunque se produce más formol de lo que se adicionaría como antiséptico en la forma de hexametilenetetramina. Nosotros hemos encontrado en varios productos preparados (algunos por nosotros mismos) los tenores de formol expresados en miligramos, que se dan en Tabla I.

Varios resultados fueron sorprendentes; los relativos a los arenques semi-ahumados parecen bajos, si se tiene en cuenta la aportación de formol del humo; los del bacalao salado y conservas de camarón de Marruecos parecen extraordinariamente elevados, si se comparan, por ejemplo, con los de anchoas saladas y conservas de camarón Noruego.

El contenido de formol parece, efectivamente, tener poca relación con el grado de ahumado del arenque, juzgado organolépticamente, o la proporción de fenoles.

En cuanto al elevado contenido del bacalao salado y del camarón de Marruecos, esto lo explica el hecho de que el primero se trata usualmente con bisulfito de sodio para blanquearlo, y el otro con sulfito de sodio para evitar el ennegrecimiento enzimático, en tanto que ni las anchoas saladas ni el camarón de Noruega se tratan así. El ión sulfuroso se combina instantáneamente con el radical aldehído y activa el desdoblamiento del óxido de trimetilamina. El bisulfito resultante se descompone con liberación de formol cuando se dosifica en un medio ácido. Las proporciones de formol y de anhidrido sulfurosa están estrechamente relacionadas, particularmente en el bacalao salado, en el que apenas existen intercambios ulteriores con el ambiente.

El estudio estadístico de los resultados obtenidos con unas 60 muestras de bacalao demuestra que el formol procede del óxido de trimetilamina y que no ha sido añadido.

En conclusión, parece ser que el formol se forma naturalmente en los preparados de pescado o crustáceos. La cantidad de formol puede aumentar mucho después de un tratamiento con sulfito o ácido sulfuroso, lo que tiene que aceptarse como una consecuencia normal en las disposiciones de higiene de los alimentos que permiten esta clase de tratamiento.

TABLEAU I

Teneurs en formaldéhyde de diverses préparations de poissons et de crustacés

	Nombre examiné	*mg. formol par kg. matière fraiche*	*mg. formol par kg. matière sèche*
Poisson frais . . .	9	19 à 175	
Poisson congelé . .	19	1 à 59,5	3 à 248
Anchois salé . .	22	5 à 51,2 (30,8)	
Morue salée . . .	69	23 à 470	48 à 989
Filets de harengs saurs .	18	10 à 116 (47,4)	30 à 255
Conserves de crevettes de Norvège . . .		4 à 19	
Conserves de crevettes du Maroc . . .	14	95 à 210	
Conserves de crustacés divers . . .		12 à 30	

ENZYMES OF MARINE FISH MUSCLE AND THEIR ROLE IN FISH SPOILAGE

by

GUNTHER SIEBERT

Fish muscle is well known for its easy digestibility. The efficient attack of enzymes on fish muscle proteins is regarded as one of the factors which cause the rapid spoilage of fishes after their death. Therefore some studies were undertaken of the properties of proteolytic enzymes in fish muscle and other tissues. Fish muscle contains very active cathepsins able to split up to 10 mg. of protein per hour per g. fresh muscle tissue (Table I). These cathepsins are of true muscular origin and occur in an active state (without endogenous inhibitors). However, freshly-caught fish display a penetration of digestive enzymes from the gut through the abdominal cavity into the muscular tissue, if the digestive tract is not carefully removed within a short time after the capture of the fish; e.g. trypsin from the intestine increases about 8 times in the abdominal cavity (which seems to contain some enzymes by itself) and in the abdominal part of the muscles within 4 hours' storage aboard the trawler (Table II).

Fish muscle is also very rich in peptidases; figures for the cleavage of 20 different peptides are given in comparison with the considerably smaller figures for mammalian muscle (Table III). Some questions of the ratio of cathepsin *versus* peptidase activities and of the specificities concerned are discussed. Cod muscle splits up to 125 mg. of a peptide per hour per g. fresh tissue. Cathepsin from cod muscle has been purified about ninetyfold and some enzymatic properties were studied. The pH-optimum is near pH 4·3. The enzyme is strongly inhibited by Co^{++} ions (31 per cent at 10^{-5} *M*), but much weaker by Hg^{++} ions (13 per cent at 10^{-3} *M*). No activation was found by any metal ion; however, cyanide does activate (181 per cent at 10^{-4} *M*), and several sulphydryl reagents are inhibitory (*p*-chloromercuribenzoate, *o*-iodosobenzoate, iodoacetamide) (Table IV). It is concluded from these data that cod muscle cathepsin contains disulfide linkages as well as sulphydryl groups. This cathepsin, together with several other cod muscle enzymes, has about the same resistance against heat denaturation as mammalian enzymes. The temperature coefficient also is found in the usual range (Q_{10} 1·86 between 27° and 17°C, Q_{10} 2·45 between – 3° and – 13°C) (Table V).

A great difference, however, exists as to the substrate specificity of cod muscle cathepsin. None of the substrates known as susceptible for mammalian cathepsins A, B, and C, is split by cod muscle cathepsin. Therefore, an investigation of the substrate specificity was begun by using cod spleen cathepsin as a model for fish cathepsins. Cod spleen cathepsin is about 20–40 times more active than cod muscle cathepsin. The fiftyfold purification, so far achieved, corresponds to an activity of about 1/4 as compared with crystalline digestive proteases like trypsin, pepsin, etc. We hope to have elucidated the specificity of the cod cathepsins quite soon (Table VI).

In conclusion, proteolytic enzymes occur in fish muscle to such an abundance that the assumption seems justified that they play an important rôle in fish spoilage, by degrading fish muscle proteins, and by furnishing amino acids and peptides for the growth of microorganisms. A still better knowledge of these enzymes might finally help in providing man with as good and as much seafood as possible.

LES ENZYMES MUSCULAIRES DES POISSONS MARINS ET LEUR ROLE DANS L'ALTERATION DU POISSON

Le poisson est réputé pour sa facile digestibilité. L'attaque, avec des résultats effectifs, des protéines musculaires du poisson par les enzymes est considérée comme l'un des facteurs d'altération rapide des poissons après leur mort. De ce fait, on a conduit quelques recherches sur les propriétés des enzymes protéolytiques dans les muscles et les autres tissus du poisson.

Le muscle de poisson contient des cathepsines très actives, capables d'attaquer jusqu'à 10 mg. de protéine par heure, par gramme de tissu musculaire frais (Tableau I). Ces cathepsines sont d'origine musculaire vraie et apparaissent sous forme active (sans inhibiteurs endogènes). Cependant, les poissons fraîchement pêchés montrent une pénétration des enzymes digestives depuis l'intestin à travers la cavité abdominale et vers le tissu musculaire, si le tractus digestif n'est pas soigneusement enlevé peu de temps après la capture du poisson. Par exemple, la trypsine provenant de l'intestin augmente 8 fois environ dans la cavité abdominale (qui semble contenir elle-même quelques enzymes) et dans la zone abdominale des muscles en quatre heures d'entreposage à bord d'un chalutier (Tableau II).

Le muscle de poisson est très riche également en peptidases; on présente des schémas de clivage de 20 peptides différents que l'on compare avec le nombre bien inférieur que présente le muscle de mammifère (Tableau III). On examine quelques questions concernant le rapport de la cathepsine aux activités des peptidases et à leurs caractères spécifiques. Le muscle de morue attaque jusqu'à 125 mg. de peptide par heure par g. de tissu frais.

On a purifié 90 fois approximativement de la cathepsine de muscle de morue et on a étudié quelques propriétés enzymatiques. Le pH optimum est voisin de pH 4,3. L'enzyme est fortement inhibée par les ions Co^{++} (31 % à 10^{-5} *M*), mais plus faiblement par les ions Hg^{++} (13 % à 10^{-3} *M*). On n'a trouvé aucune activation par les ions métalliques, mais on en a trouvé pour le cyanure (181 % à 10^{-4} *M*) et plusieurs réactifs sulphydrilés ont une action inhibitrice (*p*-chloromercuribenzoate, *o*-iodobenzoate, iodoacétamide) (Tableau IV). Ces données permettent de conclure que la cathepsine de muscle de morue contient des liaisons bisulfures comme des groupes sulphydriles. Ce cathepsine, avec plusieurs autres enzymes du muscle de la morue, montre approximativement la même résistance à l'altération thermique que les enzymes de mammifères. Le coefficient de température a révélé également une variation inhabituelle (Q_{10} 1,86 entre 27° et 17°C, et Q_{10} 2,45 entre – 3° et – 13°C) (Tableau V).

La cathepsine du muscle de morue présente cependant une grande spécificité à l'égard du substrat. Aucun des substrats connus pour être attaqués par les cathepsines de mammifère A, B et C n'est attaqué par la cathepsine du muscle de morue. On a entrepris en conséquence des recherches sur la spécificité de substrat en utilisant de la cathepsine de rate de morue comme modèle des cathepsines de poisson. La cathepsine de rate de morue est 20 à 40 fois plus active que la cathepsine de muscle de morue. La purification à 50 fois, effectuée jusqu'ici, correspond à une activité du 1/4 de celle des protéases digestives cristallisées telles que la trypsine, la pepsine, etc. Nous espérons que nous aurons bientôt élucide la spécificité des cathepsines de morue (Tableau VI).

En conclusion, les enzymes protéolytiques se présentent dans le muscle de poisson avec une telle abondance qu'il semble justifié de penser qu'elles jouent un rôle important dans l'altération du poisson en dégradant les protéines du muscle de poisson et en fournissant au développement des micro-organismes des aminoacides et des peptides. Une connaissance encore meilleure de ces enzymes pourra contribuer en fin de compte à fournir à l'homme des aliments marins aussi bons et abondants que possible.

ENZIMAS DEL TEJIDO MUSCULAR DEL PESCADO DE MAR Y SU PAPEL EN LA DETERIORACION

Es bien conocido el elevado grado de digestibilidad del tejido muscular del pescado. La intensidad del ataque de los enzimas contra las proteínas de dicho tejido se considera como uno de los factores que causan su rápida deterioración después de la muerte. Por esta razón se realizaron estudios de las propiedades de los enzimas proteolíticos del tejido muscular y otros del pescado.

Contiene el tejido muscular del pescado catepsinas muy activas capaces de fraccionar hasta 10 mg. de proteína por hora por gramo de tejido muscular fresco (Tabla I). Estas catepsinas son de verdadero origen muscular y existen en estado activo (sin inhibidores endógenos). Sin embargo, en el pescado recién capturado se da una invasión de enzimas digestivos que comienza en las vísceras, atraviesa las paredes de la cavidad abdominal y llega al tejido muscular, a menos que el canal digestivo se quite inmediatamente después de la captura. La tripsina de los intestinos aumenta unas 8 veces en la cavidad abdominal (que también parece contener algunos enzimas) y en el tejido muscular que la rodea a las 4 horas de almacenamiento a bordo del arrastrero (Tabla II).

También abundan las peptidasas en el tejido muscular del pescado. Se dan los datos de desdoblamiento de 20 péptidos diferentes y se comparan con las cifras mucho más pequeñas correspondientes al tejido muscular de los mamíferos (Tabla III). Se exponen algunos aspectos de la relación entre las actividades de la catepsina y la peptidasa y de las especificidades concernientes. Cada gramo de tejido muscular fresco de bacalao desdobla hasta 125 mg. de un péptido por hora. Con su catepsina se han hecho hasta 90 purificaciones y se han estudiado algunas propiedades enzímicas. El pH óptimo está en las proximidades de 4,3. El enzima se inhibe vigorosamente por iones Co^{++} (31 % a 10^{-5} *M*), y mucho menos por iones Hg^{++} (13 % a 10^{-3} *M*). No hay activación por parte de ningún ión metálico, aunque el cianuro lo activa (181 % a 10^{-4} *M*) y varios reactivos sulfhidrilos lo inhiben (*p*-cloromercuribenzoato, *o*-yodosobenzoato, yodoacetatoamida) (Tabla IV). Se desprende de estos datos que la catepsina del tejido muscular del bacalao contiene enlaces disulfido y grupos sulfhidrilo. Esta catepsina, junta con varias otras enzimas del tejido muscular del bacalao, ofrece la misma resistencia, aproximadamente, a la desnaturalización térmica que los enzimas de mamíferos. El coeficiente de temperatura también se encuentra en la gama usual (Q_{10} 1,86 entre 27° y 17°C., Q_{10} 2,45 entre − 3° y − 13°C.) (Tabla V).

Sin embargo, existe una gran diferencia en cuanto a la especificidad de la catepsina del tejido muscular de bacalao. Ninguno de los substratos conocidos como susceptibles a las catepsinas A, B y C de los mamíferos lo desdoblan las catepsinas del tejido muscular de bacalao. Por esta razón se inició una investigación de la especificidad del substrato empleando catepsina del bazo del bacalao como modelo de catepsinas de pescado. Dicha catepsina es de 20 a 40 veces más activa que la del tejido muscular. La quincuagésima purificación lograda hasta ahora corresponde a una actividad de una cuarto parte de proteasas digestivas cristalinas como tripsina, pepsina, etc. Confiamos elucidar en breve la especificidad de la catepsina de bacalao (Tabla VI).

En conclusión, los enzimas proteínicos existen en el tejido muscular del pescado en tal abundancia, que parece estar justificado suponer que desempeñan un importante papel en la deterioración del pescado al degradar las proteínas de su tejido muscular y crear aminoácidos y péptidos para el desarrollo de microorganismos. Un conocimiento más completo de estos enzimas podría contribuir a suministrar al hombre de grandes cantidades de pescado de excelente calidad.

TABLE I

Catheptic activities in fish tissues

	Muscle	*Liver*	*Spleen*
Fishes			
(cod, herring	3·9	48	164
flounder, sole)	(0·6)	(4·2)	(11·7)
Mammals			
(rat, rabbit, pig, ox)	0·45	9	26

Figures as μM. tyrosine/hr./g. tissue (μM. tyrosine/hr./mg. protein).

TABLE II

Alterations in enzyme activities during storage of cods on deck of trawler

Storage time (hours)	0	2	4	8
Trypsin, abdominal cavity	100	310	760	8,100
Amylase, abdominal cavity	100	510	710	1,400
Trypsin, abdominal muscle	100	190	860	4,650
Amylase, abdominal muscle	100	—	—	140
Trypsin, back muscle	100	—	—	130

Figures as percentage change.

TABLE III

Peptidases in cod muscle

	Cod muscle / *Pig muscle*		*Cod muscle* / *Beef muscle*
17 *different peptides*	2·5		1·8
	Cod	*Pig*	*Beef*
Gly-gly	500	225	194
Gly-gly-gly	0	256	162
L-ser-gly	532	62	75
Gly-L-thre	635	122	288

Figures as μM./hr./g. fresh tissue.

TABLE IV

Properties of cod muscle cathepsin

Activity (μM. tyrosine/hr./mg. protein)	crude 0·1; purified 9·0				
Preparation (5 steps)	90-fold purification 6% yield				
pH-optimum	pH 4·3				
No activity like cathepsins A, B, or C, Carboxypeptidase, leucine aminopeptidase					
SH-reagents (each $10^{-4} M$ final conc.)	cyanide			181	
	sulphide			110	
	p-Cl-Hg-benzoate			66	(% activity of control)
	iodoacetamide			65	
	iodosobenzoate			71	
Metals (each $10^{-3} M$ final conc.)	Versene	98	Fe^{++}	108	
	Hg^{++}	87	Ni^{++}	68	
	Zn^{++}	90	Mn^{++}	85	
	Co^{++}	48	Mg^{++}	97	

TABLE V

Heat stability and temperature coefficient

Enzyme (cod muscle)	*Temperature for 50% inactivation (1 hr.)*	Q_{10}	*Temperature range from*	*to*
Cathepsin, purified	52	1·86	27	17
		2·13	17	7
		2·41	7	−3
		2·45	−3	−13
Glycylglycine dipeptidase, crude	42	1·66	37	27
		2·67	12	2
6 other enzymes (glycolytic, oxidative)	30–52	—	—	—

TABLE VI

Properties of cod spleen cathepsin

Activity (μM. tyrosine/hr./mg. protein)	crude 3·0; purified 155				
Preparation (4 steps)	52-fold purification 20% yield				
pH-optimum	pH 5·1				
No activity like cathepsin A, B, or C, Carboxypeptidase, leucine aminopeptidase					
SH-reagents (each $2 \times 10^{-3} M$ final conc.)	cyanide			124	
	cysteine			89	
	p-Cl-Hg-benzoate			38	(% activity of control)
	iodoacetamide			94	
	iodosobenzoate			67	
	N-ethyl maleineimide			120	
Metals (each $2 \times 10^{-3} M$ final conc.)	Hg^{++}	0	Co^{++}	94	
	Cu^{++}	0	Mn^{++}	106	
	Zn^{++}	93	Mg^{++}	114	

ENDOGENOUS PROTEOLYTIC ENZYMES AND THEIR ACTION ON WATER-SOLUBLE FISH TISSUE PROTEINS

by

A. M. DOLLAR and C. M. BLACKWOOD

A study was made of the properties and activities of proteinases in kidney tissues of codfish (*Gadus macrocephalus*) and rockfish (*Sebastodes caurinus* and *S. auriculatus*) during storage of the fish in ice. Kidney proteinases were partially purified, and used to study changes developing in muscle tissue proteins during ice storage of the fish, in an attempt to define the potential relationship of proteolysis to changes in tissue quality during the early stages of spoilage before the formation of small molecular products conventionally used as indexes of spoilage.

The enzyme methods were basically those of Anson (J. Gen. Physiol. 1937; **20**, 565–574), using bovine hemoglobin as substrate. Cod hemoglobin was tried as a substrate, but was found to be unstable and gave non-uniform results. Distilled water was used to prepare proteinase extracts of the kidney tissues, since there was no improvement in the total extracted activity when sodium chloride solutions of increasing concentrations were used.

The end products of enzyme activity were measured at 280 μ, using the clarified supernatant solution from the reaction mixture treated with trichloroacetic acid.

Both codfish and rockfish kidney proteinases had pH optima between 3 and 3·5 and at 6·5; activity was greatest between pH 3 and 3·5. These enzymes were relatively stable between pH 3 and 7, but were rapidly and irreversibly destroyed below pH 2·5. Greatest stability occurred at pH 6·8.

The cod kidney proteinases had a Q_{10} value of approximately 2·0. Fish tissue proteins stored at room temperature were hydrolysed by their endogenous proteinases at 4 to 5 times the rate for fish stored at 0°C. The proteinases were rapidly inactivated at temperatures above 30°C, but were stable below 20°C. Proteinases in frozen kidney tissue and partially purified kidney proteinases were relatively stable when stored for two to four weeks at − 30°F.

Kidney proteinase activity increased rapidly during the first three days' ice storage of codfish, and then decreased steadily from three to nine days to below the 0 day level. From nine to thirteen days there was a second increase in activity.

A significant invasion of kidney by bacteria occurred after one week of ice storage. However, the proteinase activity of these bacteria was very low, and could not account *per se* for the increase in activity.

The decomposition of globular fish muscle proteins may arise from an alteration of their intramolecular structure, causing an increased susceptibility to enzymatic hydrolysis. This hypothesis is supported by studies using partially purified rockfish kidney proteinases as "probes" to detect changes in water-soluble rockfish skeletal tissue proteins during storage in ice.

Partial purification of the proteinases was achieved by water extraction of ground kidney tissue at pH 6·8, adjustment of pH to 3·5, and fractional precipitation by ammonium sulfate. The 40 to 70 per cent ammonium sulfate fraction gave the largest and most pure proteinase precipitate.

The semi-purified kidney proteinases were allowed to act on water soluble protein extracts prepared from whole rockfish stored in ice for intervals up to 14 days. The rate of hydrolysis of the extracted proteins increased during the first five to six days of storage in ice, and then the rate decreased steadily for the ensuing nine days.

Partially purified rockfish kidney proteinases were able sensitively and accurately to detect early post-mortem changes in water-soluble rockfish tissue proteins during storage of fish in ice.

Since mixtures of enzymes can attack a great variety of peptide bond linkages, the invasion of fish tissues by micro-organisms and subsequent hydrolysis by mixtures of endogenous and exogenous proteinases and peptidases is of great importance in the post-mortem degradation of proteins in fish skeletal muscle.

LES ENZYMES PROTEOLYTIQUES ENDOGENES ET LEUR ACTION SUR LES PROTEINES HYDROSOLUBLES DES TISSUE DU POISSON

On a fait des recherches sur les propriétés et les activités des protéinases dans les tissus rénaux de la morue (*Gadus macrocephalus*) et du rockfish (*Sebastodes caurinus* et *S. auriculatus*) durant leur entreposage sous glace. Les protéines rénales ont été purifiées partiellement et utilisées pour effectuer l'étude des modifications qui interviennent, durant l'entreposage sous froid du poisson, dans les protéines des tissus musculaires; cette étude visait à définir les relations potentielles de la protéolyse et des modifications qualitatives des tissus durant les premiers stades de l'altération, avant que ne se forment les petits produits moléculaires utilisés d'une façon classique comme indices de l'altération.

Les méthodes enzymatiques étaient essentiellement celles d'Anson, (J. Gen. Physiol. 1957; **20**, 565–574), avec l'hémoglobine de boeuf. L'hémoglobine de la morue a été essayée comme substrat, mais elle s'est révélée instable et n'a pas apporté de résultats uniformes. On a utilisé de l'eau distillée pour préparer les extraits de protéinase dans les tissus rénaux, car il n'y avait pas d'amélioration dans l'activité totale des extraits quand on employait des solutions de chlorure de sodium à concentrations croissantes.

Les produits finaux de l'activité enzymatique ont été mesurés à 280 μ en utilisant la solution surnageante clarifiée du mélange de réaction traité avec l'acide trichloracétique.

Les protéinases rénales de la morue comme celles du rockfish présentaient des pH optima entre 3 et 3,5 et à 6,5; l'activité était la plus grande entre 3 et 3,5. Ces enzymes étaient relativement stables entre pH 3 et 7, mais elles étaient détruites d'une façon rapide et irréversible au-dessous de pH 2,5. La plus grande stabilité apparaissait à pH 6,8.

Les protéinases rénales de la morue avaient un indice Q_{10} de 2,0 environ. Les protéines des tissus du poisson entreposées à la température du laboratoire étaient hydrolysées par leurs protéinases endogènes à un taux 4 ou 5 fois plus fort que pour le poisson entreposé à 0°C. Les protéines étaient rapidement inactivées au-dessus de 30°C, mais restaient stables au-dessous de 20°C. Les protéinases dans les tissus rénaux congelés et les protéinases rénales partiellement purifiées étaient relativement stables quand elles étaient entreposées durant 2 à 4 semaines à −30°C.

L'activité des protéinases rénales augmentait rapidement durant les trois premiers jours d'entreposage sous glace de la morue, puis décroissait ensuite continuellement du 3ᵉ au 9ᵉ jour jusqu'au dessous du niveau du jour initial. Du 9ᵉ au 13ᵉ jour, il y avait un second accroissement de l'activité.

Une invasion très nette du rein par les bactéries apparaissait après une semaine d'entreposage sous glace. Cependant, l'activité propre des protéinases de ces bactéries était très faible, et on ne peut pas attribuer à elle seule ce deuxième accroissement de l'activité.

La décomposition des protéines globulaires des muscles du poisson peut être une conséquence d'une altération de leur structure intramoléculaire entraînant une susceptibilité accrue à l'hydrolyse enzymatique. Cette hypothèse est appuyé par des études utilisant des protéinases rénales partiellement purifiées de rockfish comme témoins pour détecter les changements dans les protéines hydrosolubles des tissus du squelette de rockfish durant l'entreposage sous glace.

Une purification partielle des protéinases a été effectuée par extraction aqueuse des tissus broyés de reins au pH 6,8, réajustement du pH à 3,5 et précipitation fractionnée au sulfate d'ammonium. La fraction de 40 à 70% de sulfate d'ammonium donne le précipité de protéinase le plus important et le plus pur.

On a laissé agir des protéinases rénales semi-purifiées sur des extraits protéiques hydrosolubles obtenus depuis du rockfish entier entreposé sous glace durant des périodes atteignant 14 jours. Le taux d'hydrolyse des protéines extraites augmentait durant les premiers cinq ou six jours d'entreposage sous glace, et ensuite le taux décroissait continuellement durant les neuf jours suivants.

Les protéinases rénales partiellement purifiées de rockfish étaient capables de mettre en évidence avec sensibilité et précision les premières modifications qui interviennent post-mortem dans les protéines hydrosolubles des tissus de rockfish durant son entreposage sous glace.

Etant donné que les mélanges d'enzymes peuvent attaquer une grande variété de liaisons peptidiques, l'invasion par les micro-organismes des tissus du poisson et leur hydrolyse subséquente par des mélanges de protéinases et de peptidases endogènes et exogènes présentent une grande importance dans la dégradation post-mortem des protéines dans les muscles du squelette du poisson.

ENZIMAS PROTEOLITICOS ENDOGENOS Y SU ACCION EN LAS PROTEINAS DEL TEJIDO MUSCULAR DEL PESCADO SOLUBLES EN AGUA

Se han estudiado las propriedades y actividades de las proteinasas en los tejidos del riñón del bacalao (*Gadus macrocephalus*) y gallineta (*Sebastodes caurinus* y *S. auriculatus*) durante el almacenamiento del pescado en hielo. Dichas proteinasas se purificaron parcialmente y se emplearon para estudiar los cambios que ocurren en las proteínas del tejido muscular del pescado durante el almacenamiento en hielo, con objeto de definir las posibles relaciones entre la proteólisis y los cambios en la calidad del tejido durante las primeras fases de la deterioración, antes de la formación de productos moleculares empleados normalmente como índices de deterioración.

Los métodos enzímicos eran fundamentalmente los de Anson (J. Gen. Physiol. 1937; **20**, 565–574), empleando hemoglobina de ganado bovino como substrato. También se ensayó como substrato la hemoglobina de bacalao, pero resultó ser inestable y no dio resultados uniformes. El agua destilada se empleó para preparar extractos de proteinasa del tejido del riñón, por no mejorar la actividad extractada total cuando se empleaban soluciones de cloruro sódico en concentraciones crecientes.

Los productos finales de la actividad enzímica se midieron a 270 μ empleando la solución sobrenadante clarificada de la mezcla de la reacción, tratada con ácido tricloroacético.

Tanto las proteinasas del riñón del bacalao como de la gallineta tenían pH óptimos comprendidos entre 3 y 3,5 y 6,5; la actividad era mayor entre 3 y 3,5. Estos enzimas eran relativamente estables a pH entre 3 y 7, pero se destruían rápida e irreversiblemente por debajo de ph 2,5. La mayor estabilidad ocurría a pH 6,8.

Las proteinasas del riñón del bacalao tenían un índice Q_{10} de, aproximadamente, 2,0. Las proteínas de tejido muscular de pescado almacenadas a temperatura ambiente eran hidrolizadas por sus proteinasas endógenas 4 ó 5 veces más rápidamente que en el caso del pescado almacenado a 0°C. Las proteinasas perdían rápidamente la actividad a temperaturas superiores a 30°C., pero eran estables por debajo de 20°C. Las proteinasas de tejido de riñón congelado y las de riñón parcialmente purificado eran relativamente estables cuando se almacenaban de 2 a 4 semanas a −30°C.

La actividad de la proteinasa de riñón de bacalao aumentaba rápidamente durante los 3 primeros días en que el pescado estaba almacenado en hielo, y después disminuía uniformemente de 3 a 9 días hasta alcanzar una concentración más baja que en el primer día. Del 9° al 13° día había un segundo aumento en la actividad.

Después de una semana de almacenamiento en hielo hubo una importante invasión del riñón por las bacterias, pero la actividad proteinasa de éstas era muy baja y no se le podía atribuir *per se* el aumento de la actividad.

La descomposición de las proteínas globulares del tejido muscular del pescado puede deberse a una alteración de su estructura intramolecular que produce un aumento de la susceptibilidad a la hidrólisis enzimática. Esta hipótesis la confirman los estudios en los que se usan proteinasas de riñón de gallineta parcialmente purificadas como "exploradoras", para determinar los cambios en las proteínas del tejido esquelético de la gallineta solubles en agua, durante su almacenamiento en hielo.

La purificación parcial de las proteinasas se logró por extracción en agua de tejido de riñón molido, a pH 6,8, ajustando el pH a 3,5 y precipitación fraccionada por sulfato de amonio. La fracción de sulfato de amonio de 40 a 60% dio el precipitado de proteinasa mayor y más puro.

Las proteinasas del riñón semipurificadas se dejaron actuar sobre extractos de proteína solubles en agua, preparados a partir de gallineta entera almacenada en hielo, por períodos hasta de 14 días. La velocidad de hidrólisis de las proteínas extractadas aumentó durante los primeros 5 ó 6 días de almacenamiento en hielo y después disminuyó uniformemente durante los 9 días siguientes.

Las proteinasas de riñón de gallineta purificadas parcialmente fueron capaces de determinar con sensibilidad y precisión los primeros cambios post mortem en proteínas de tejido muscular de gallineta solubles en agua, durante el almacenamiento del pescado en hielo.

Como las mezclas de enzimas son capaces de atacar una gran variedad de enlaces péptido, la invasión del tejido muscular del pescado por microorganismos y posterior hidrólisis por mezclas de proteinasas y peptidasas endógenas y exógenas, reviste la mayor importancia en la degradación post mortem de las proteínas de los músculos esqueléticos del pescado.

DISCUSSION

On Mr. Stansby's paper, Mr. F. Bramsnaes (Denmark) observed: The reported thiamine values appear to be high, whereas the reported riboflavin values seem to be too low. Has the thiaminase content been considered? From which species were the riboflavin data obtained?

Mr. M. Stansby (U.S.A.): You are probably correct on thiamine and thiaminase. The data on riboflavin are probably from an unusual species.

Dr. H. S. Olcott (U.S.A.): The histidine content of tuna is very important, because histidine is capable of losing an amino group to become histamine, which is toxic.

On Dr. Bramstedt's paper, Mr. F. Bramsnaes (Denmark) remarked: (1) In your paper you refer to the statement that the low connective tissue content, high water content and high free amino acid content lead to rapid spoilage. You state that there are also free amino acids present in meat, which spoils less rapidly than fish. Is it the low glycogen content that is responsible for rapid spoilage? Halibut has high glycogen content and spoils slowly.

(2) Do we have to revise our old theory of bacterial spoilage of lean fish in the light of your statements that enzymes are largely responsible for spoilage? Aseptic fish can be kept 4–6 weeks without spoilage. I would like to know your intention

in making this statement. Is it simply to call our attention to the importance of enzymes?

(3) According to your paper, lysine content shows a constant increase in spoiling muscle. In another part of your paper, however, you say that lysine shows a constant decrease. How can these two statements be reconciled?

DR. F. BRAMSTEDT (Germany): Before the main invasion of bacteria during the very early storage period, profound changes occur, due to the effect of muscle enzymes. Perhaps "spoilage" is not the right term: "change in composition" might be a better term. These changes involve glycogen, free amino acids, and peptides. I agree that bacteria play a most important rôle in spoilage. Incipient changes, however, are due to enzymes. The enzymes prepare the substrates for bacteria. So spoilage involves two steps: (1) changes due to the activity of enzymes during the first 1–5 days, and (2) changes due to the activity of bacteria after that period. Free lysine first decreases; then, as enzymes hydrolyse, the protein-free lysine increases. In fact, there are different processes involved.

DR. G. HAMOIR (Belgium): The changes occurring in muscle after death have been investigated by Crotos, Bate, Smith and Bendall on rabbit muscle. Rigor mortis is observed when the phosphagen is broken down and when the adenosine-triphosphate level is low enough. It is this decrease in ATP which induces the change of the mechanical properties of muscle and the loss of extractability of the muscle structural proteins. Fish muscle behaves from this point of view like rabbit muscle, but deteriorates more quickly. This difference appears so far to be due to two factors: the higher proteolytic activity of this muscle, and the higher instability of its proteins. In order to place the problem of fish muscle conservation in its proper perspective (we shall not consider here the subsequent bacterial invasion), it is important first to realize that fish muscle is fundamentally similar to mammalian muscle, and secondly to assess the relative importance of the factors which are favouring the deterioration of fish muscle. It is well known from scientists working on the conservation of fish that sterile fish muscle can be kept for long periods without developing malodorous compounds, or giving rise to a significant hydrolysis of the muscle proteins. Partman has shown that the amount of amino nitrogen liberated by autolysis of carp sterile muscle is very small. Similar results have been observed after irradiating, as reported at this conference by Dr. Tarr. Furthermore, as cathepsin is present in the lysozymes, it actually occurs only after destruction of the membrane of these particles. The importance of the proteolytic activity of fish muscle for its spoilage does not seem therefore to me well established so far.

On the other hand, the lower content of stroma proteins in fish muscle, the easier extractability of fish actin and the lower stability of isolated fish myosin are well known. It is clear that the structure of the fish muscle cell is more easily altered than the one of the mammalian muscle cell. It would therefore be desirable to improve the isolation of the fish muscle structural proteins and to study their stability under various conditions. Further research in this direction appears in our opinion more promising in order to improve the conservation of fish muscle.

DR. H. L. A. TARR (Canada): Was there any evidence of sugar-amino acid reaction occurring during the decrease of amino acids, or was this decrease due to decarboxylation?

DR. F. BRAMSTEDT (Germany): There was no evidence; but I believe that it was due to decarboxylation.

On DR. JEBSEN's paper, DR. M. M. A. KADER (U.A.R.) asked: Has Dr. Jebsen studied the relationship between the length of the carbon chain of the free amino acids and the degree of degradation of proteins? Was pyridine further oxidized during degradation?

DR. J. JEBSEN (Norway): I have no further data on the degradation of lysine to pyridine. This was only one possible pathway. There is no evidence that nicotinic acid could be formed from pyridine. In carrying out these researches, scientists should consider standardization of methodology, so that results of researchers could be compared and readily understood by all who might be interested in this type of knowledge.

DR. A. M. DOLLAR (U.S.A.): Dr. Olcott and I have found that in myoglobin from tuna one mole of myoglobin contains one mole of sulphydryl. Tuna myoglobin is therefore distinct from mammalian myoglobin, and contains no sulphydryl groups.

On DR. DOLLAR's paper, DR. F. A. L. BRAMSTEDT (Germany) observed: Enzymes are evidently of great importance, especially during the first part of spoilage. But Dr. Dollar's slides indicated little relationship between the amount of enzymes present and their activity. I believe the activity to be an important factor in the spoilage of fish as handled commercially.

DR. A. M. DOLLAR (U.S.A.): In my own work with Dr. Olcott, and in subsequent work of Dr. Brown and Dr. Olcott, a purified myoglobin from tuna has been isolated. On analysis by the amperometric method, one mole of sulphydryl per mole of myoglobin has been found. (It is important to note that in myoglobins from mammalians there are no sulphydryl groups. The presence of sulphydryl groups in myoglobins of tuna is important.) The presence of this sulphydryl group in the myoglobin of fish results in its rapid oxidation during purification. On oxidizing, the purified protein rapidly becomes quite insoluble. In impure extracts the protein remains quite stable, possibly owing to the presence of reducing conditions, possibly owing (at least in part) to enzyme action.

DR. H. L. A. TARR (Canada): What effect has radiation upon enzyme systems, since it is well known that irradiated foods can be stored for extended periods of time?

DR. B. C. GUHA (India): Has any work been done on the possibility of reversal of inhibition resulting from the presence of glutathionine?

DR. G. SIEBERT (Germany): No studies have yet been made on this last point, so far as I know. I have to report, however, that in my experimental work the versene was present; moreover, the pH was properly adjusted. Any discrepancy, therefore, might be due to these differences. It was certainly possible that results might be affected by irradiation; i.e. enzyme stability may have been affected by this process.

DR. H. L. A. TARR (Canada): Work on cathepsin and the effect of copper has proved very interesting. Cathepsin, however, occurs inside the particles, and is active only after the particles have been destroyed by such processes as freezing or cold storage. Have any experiments been carried out on factors causing the rupture of these particles?

DR. G. SIEBERT (Germany): Research had been done on methods of extracting the enzymes; the results show that the enzymes are bound, and set free only under drastic treatment.

DR. A. M. DOLLAR (U.S.A.): Water, which disrupts the cell walls, has been shown to be a better enzyme extractant than the salt solution.

Section 2: LIPIDS AND VITAMINS

THE LIPIDS OF FISH AND CHANGES OCCURRING IN THEM DURING PROCESSING AND STORAGE

by

J. A. LOVERN

Fresh fish tissues are considered under the headings of vertebrate flesh, vertebrate viscera and invertebrates. For the first two of these groups the nature of the depot lipids and the non-depot lipids is separately described; for the invertebrates that of the total lipids. For all groups the component fatty acids are discussed and representative data presented.

The commonest depot lipid in vertebrate fish is triglyceride fat; but in some Elasmobranch species alkoxydiglycerides and the hydrocarbon squalene partly or entirely take over this function. In a few species wax esters become important as depot lipids. The non-depot lipids contain a great range of compounds. Some novel lipid types have been isolated from aquatic invertebrates. Aquatic animal lipids as a whole are characterized by the high average of unsaturation and by the range of chain-lengths found in their component fatty acids. Characteristic differences occur in the fatty acids of different lipid classes, while biological factors may also be important in this respect.

The effects of processing and storage on these lipids are considered according to the agency responsible, under the following headings: micro-organisms, heat, freezing, storage temperature, dehydration, salt and biological factors. The only type of lipid degradation considered is hydrolysis, since oxidative changes are covered elsewhere. The significance of the above agencies is illustrated by examples from processes in which they are operative. The most detailed information concerns the effects of freezing and of storage temperature on reaction rates. The final section discusses what little is known of the effects of such lipid hydrolysis on culinary quality.

LES LIPIDES DES ANIMAUX MARINS ET LEURS MODIFICATIONS DURANT LE TRAITEMENT ET L'ENTREPOSAGE

Les tissus d'animaux marins frais sont étudiés sous les titres principaux de: chair de vertébrés, viscères de vertébrés, et invertébrés. Pour les deux premiers groupes on decrit séparément la nature des lipides de dépôt et celle des lipides qui ne se déposent pas, et pour les invertébrés, celle des lipides totaux. Pour tous ces groupes, on étudie les acides gras composants et on présente des données représentatives.

Le dépôt lipidique le plus commun dans les animaux marins vertébrés consiste en triglycéride; mais dans quelques espèces d'Elasmobranches cette fonction est partiellement ou entièrement assurée par les alkoxyglycérides et le squalène. Dans quelques espèces, des esters cireux jouent un rôle important comme dépôt lipidique. Les lipides circulatoires contiennent une grande variété de composés. Quelques types nouveaux de lipides ont été isolés des invertébrés aquatiques. Les lipides des animaux aquatiques dans leur ensemble sont caractérisés par leur haute insaturation moyenne et par l'intervalle de variation des longeurs de chaînes présenté par leurs acides gras composants. Des différences caractéristiques apparaissent dans les acides gras des différentes classes de lipides, tandis qu'à cet égard les facteurs biologiques peuvent être également importants.

Les effets du traitement et de l'entreposage sur ces lipides sont considérés en fonction des agents responsables, sous les titres principaux suivants: micro-organismes, chaleur, congélation, température d'entreposage, déshydratation, sel et facteurs biologiques. Le seul type de dégradation lipidique considéré est l'hydrolyse, car les changements dus à l'oxydation sont étudiés par ailleurs. Le rôle significatif des agents précédemment indiqués est illustré par des échantillons prélevés au cours des opérations où ils interviennent. Les renseignements les plus détaillés concernent les effets de la congélation et de la température d'entreposage sur les taux de réaction. En section finale, on examine le peu que l'on connaisse sur les effets d'une telle hydrolyse des lipides sur la qualité culinaire.

LIPIDOS DEL PESCADO Y CAMBIOS QUE OCURREN EN ELLOS DURANTE LA ELABORACION Y EL ALMACENAMIENTO

Los tejidos del pescado fresco se examinan bajo los epígrafes de carne de vertebrados, vísceras de vertebrados e invertebrados. Para los dos primeros grupos, la naturaleza de los lípidos de reserva y de los de uso constante se describen por separado; en el caso de los invertebrados se describen los lípidos totales. En todos los casos se citan los ácidos grasos componentes y se presentan datos representativos.

El lípido de reserva más común en el pescado vertebrado es la grasa de los triglicéridos, pero en algunas especies de elasmobranquios, los alcoxidiglicéridos y el escualeno desempeñan esta función parcial o completamente. En unas pocas especies los ésteres de la cera adquieren importancia como lípidos de reserva. Los lípidos de uso continuo contienen una gran diversidad de compuestos. Algunos tipos nuevos de lípidos se han aislado a partir de invertebrados acuáticos. En su conjunto, los lípidos de los animales acuáticos se caracterizan por su alto promedio de insaturación y amplitud de las longitudes de las cadenas que se encuentran en sus ácidos grasos componentes. Existen diferencias características en los ácidos grasos de diversas clases de lípidos y aun los factores biológicos pueden revestir importancia en este particular.

Los efectos de la elaboración y almacenamiento en estos lípidos se estudian de acuerdo con el agente causante de ellos, bajo los siguientes epígrafes: micro-organismos, sabor, congelación, temperatura de almacenamiento, deshidratación, sal y factores biológicos. El único tipo de degradación de lípidos considerado es la hidrólisis, ya que los cambios causados por la oxidación se tratan en otro lugar. La importancia de los agentes citados se ilustra mediante muestras de los procesos en los que están activos. La información más detallada concierne a los efectos de la congelación y la temperatura de almacenamiento en las velocidades de reacción. La sección final menciona lo poco que se sabe hasta ahora de los efectos de la hidrólisis de los lípidos en la calidad culinaria.

IN any review with so comprehensive a title as the above, it is well to begin with a few definitions. It is also desirable to outline the limits which have been set to the scope of the subject matter.

Lipids have been defined (1) (2) as a group of compounds having certain properties in common. Thus they are insoluble in water, but soluble in organic solvents such as ether, chloroform and benzene. They are derivatives, or potential derivatives, of higher fatty acids. Although this definition is far from adequate to meet all cases, it is hard to improve on it without loss of conciseness and it forms the basis of the first limitation of the subject matter below. Certain compounds, which are lipids by the above definition, are often also placed in other groups according to the purpose of the classification. Thus the fat-soluble vitamins are more appropriately grouped with the other vitamins for nutritional consideration and will receive only passing mention in this paper. The sterols are lipids, but sterol chemistry is so specialized that it cannot be treated adequately in a review devoted mainly to other lipids. Again, therefore, sterols will only receive limited attention in this discussion. For groups of lipids other than sterols and fat-soluble vitamins, a detailed treatment will be attempted.

The proximate composition of fish tissues forms the subject of another paper. Hence scant reference will be made here to the total lipid content of such tissues. However, details will be given of present knowledge of the types and relative proportions of individual lipids which make up this total lipid. The term "fish" will be taken to include aquatic invertebrates, but not aquatic mammals or aquatic birds. Aquatic invertebrates include what many English-speaking people call "shell fish".

It is impossible to include the results of all major investigations into the chemistry of fish lipids in a review of reasonable length. The range of species involved is itself of formidable magnitude. The aim will be to present a comprehensive picture of present knowledge in the field, summarizing experimental data wherever this fairly can be done.

The above definitions and limitations apply to the first part of the subject, namely the lipids themselves as they occur in living fish. The second part of the subject, namely the changes occurring in these lipids during processing or storage of the dead fish, as a food, has also been limited. Oxidative changes in lipids, like the chemistry of sterols, are sufficiently specialised and important to merit separate treatment. Another paper will deal with them. The changes discussed here are those of a hydrolytic nature, i.e. they are the result of reactions between tissue components, rather than between tissue and air. Processes are grouped according to the principles involved, rather than by type of product.

THE LIPIDS OF FRESH FISH

For present purposes it would be ideal if "fresh" could be taken as synonymous with "live". In some investigations the tissues have been obtained in pre-rigor condition. In other cases the fish have been obtained from a commercial catch, or even from a retail fish shop, and their condition has been uncertain. With skeletal muscle of vertebrate fish it is improbable that serious lipid breakdown will have occurred if the fish were fresh by organoleptic standards (see below); but it would be unsafe to assume this to apply to the lipids of other fish tissues or of invertebrates. Lipid hydrolysis, due to post-mortem enzymatic attack, could invalidate any data on the quantitative distribution of various lipids in the tissue. On the other hand, it is unlikely that such hydrolysis would seriously affect data on the fatty acid composition of individual lipids, other than that of such partial hydrolysis products as lysophosphatides. In particular, data on the fatty acid composition of fish depot fats are unlikely to be influenced by staleness of the raw material.

With these considerations in mind, an account may now be given of the lipid composition of fresh fish tissues. This will be done under a series of subheadings.

1. The lipids of vertebrate fish flesh

While a great deal of information has been collected about the amount and composition of triglyceride fat in those fish which use the skeletal musculature as a fat depot, the same is not true for other lipids, such as phospholipids. Moreover, much of what information there is on the non-depot lipids of fish flesh is unreliable, because of the inadequate and selective extraction techniques employed, and of the inadequate separation and analytical procedures used to study the extracted lipid mixtures.

Since the data are less ambiguous, and from the nutritional aspect of more obvious significance, the depot lipids may be treated first.

1.1. Depot lipids in vertebrate fish flesh. As a general guide, a lipid will be regarded as an energy reserve, i.e. a depot "fat", when it forms appreciably more than 1 per cent of the fresh muscle weight. Examination of numerous species of fish (see below) has shown that the total of non-depot lipids of all types seldom appreciably exceeds 1 per cent in the flesh, particularly if the "dark" muscle is removed, Reference to dark muscle raises the question of other tissues which are closely associated with the skeletal muscle, namely skin and subcutaneous connective tissue. Unless these are removed, data on lipid content may be misleading, e.g. in flatfish (sole, halibut, etc.) which sometimes have appreciable deposits of subcutaneous fat.

Data on the actual content of fat in the flesh of various species, and the seasonal and other variations in such content, belong to the subject matter of another paper. Of more concern here is the chemical nature of these depot lipids. In the overwhelming majority of species they consist of triglycerides, just as they do in most other vertebrate animals and also, incidentally, in most higher plants. Examples of fish in which the flesh depot lipids consist essentially of triglycerides are herring, sardine, pilchard, menhaden, anchovy, mackerel, tuna, salmon and eel.

In a few species triglycerides are either accompanied or entirely replaced by other lipids. The Elasmobranch (cartilaginous) fishes (sharks, rays, etc.) are well-known for their numerous biochemical variations from the Teleostean (bony) fishes. Their lipid metabolism and chemistry is no exception. Some Elasmobranchs utilize alkoxydiglycerides as depot lipids, alone or admixed with other types of lipid. Far less information is available in this respect for the flesh lipids than for the liver lipids; but the dogfish, *Squalus acanthias* (3a), the possibly identical *Squalus suckleyi* (3b), and the basking shark, *Cetorhinus maximus* (3c), all have "oily" flesh (lipid contents up to 15 per cent or so) and this "oil" is a mixture of alkoxydiglycerides and triglycerides. The ratio of these two lipid types probably varies within a species, and certainly does from species to species; e.g. one sample of *S. acanthias* flesh oil contained about 25 per cent of alkoxydiglycerides and 75 per cent of triglycerides, while two samples from *C. maximus* contained about 30 and 50 per cent respectively of alkoxydiglycerides. The chemistry of the alkoxydiglycerides will be discussed below (section 2.3.).

It should be noted that a major lipid of some Elasmobranch fish is the hydrocarbon "squalene" (see section 2.1). Squalene has not been found to be a major component of the flesh lipids of those species in which it is abundant elsewhere, (e.g. the liver (3c, d)) although it may make up small proportions (e.g. 1–3 per cent) of the flesh lipids

Although not so far reported as major lipids in the flesh of any vertebrate fish widely used as human food, it should be noted that another class of lipids, the wax esters, has been found to replace triglycerides entirely in the oil-rich flesh of fish of the genus *Ruvettus* (4), of the fish *Xenogramma carinatum* (5) and the fish *Hoplostethus islandicus* (6). Fish are not, of course, unique in using wax esters as depot lipids, since some invertebrates, some mammals and some higher plants do the same. The chemistry of these wax esters is also discussed below.

1.2. Non-depot lipids in vertebrate fish flesh. Typical non-depot lipids are the phospholipids, the sphingolipids and the sterols, none of which have ever been found to be accumulated as an energy reserve. In addition, lipids which may be so accumulated in certain tissues are usually found in much lower concentration in almost all other tissues of an organism. In these tissues it is doubtful, to say the least, whether they should be considered as energy reserves. It is usually not known whether or not they fluctuate in amount with the general nutritional state of an animal. For present purposes, however, it seems safer to ignore triglycerides in discussing non-depot lipids. Traces of wax esters and hydrocarbons are also widespread in fish tissues, but so little is known of them that again they will be ignored in the present section.

The phospholipids, sphingolipids and sterols are not distributed uniformly throughout the entire flesh of a fish. Quite apart from any selective distribution at the cellular or sub-cellular level, about which there is still a great lack of information, all these lipids can show considerable variation in concentration in different parts of the fish muscle. The most comprehensive information of this kind appears to be that of Katada *et al.* (7), a group of Japanese workers who have published a whole succession of papers on the phosphatides of fish. In the work now cited, they divided the flesh of a tuna, *Thynnus orientalis*, into both light and dark muscle. The light muscle was further subdivided into dorsal and ventral tissues, each of which was split into anterior, middle and posterior regions, and these again into external and internal tissues. The dark muscle was divided into internal and external tissues from anterior, middle and posterior regions. Thus a total of 18 regions from the flesh were separately examined. A selection of their data is given in Table I. Katada *et al.* also found about 0·01–0·06 g./100 g. of plasmalogens.

Examination of Table I shows not only the considerable extent of the variation within a single fish, but also certain trends. Thus with the light muscle the anterior ventral tissues are distinctly the richest in phosphatidyl esters and in total phospholipids, but this difference between dorsal and ventral tissues becomes less in the middle section and non-existent in the tail section. In the dorsal regions the external tissues are richer in lipids than the internal ones, but in the ventral regions there are exceptions to this. Taken as a whole, the dark muscle is the richest in total phospholipids, phosphatidyl choline, phosphatidyl serine, sphingomyelin, cerebrosides and cholesterol, but not obviously so for phosphatidyl ethanolamine.

The complexity of this mixture of lipids is apparent. Moreover, since total phospholipids in this table are the sum of those individual phospholipids which were determined experimentally, any other types of phospholipid would have been missed. The high proportions of sphingomyelin and cerebrosides reported are surprising. Muscle tissue is relatively rich in reducing sugars and in nitrogenous extractives, both of which heavily contaminate the crude lipids. Katada *et al.* used the method of Folch *et al.* (8) to purify the lipid extracts, which should have removed most of the non-lipid nitrogen and sugar. Data on crude lipid extracts of fish muscle certainly suggest high levels of cerebrosides. Thus Kaucher *et al.* (9) comment on the "unexpected finding" of a high level of cerebrosides (i.e. "lipid" galactose) in muscle tissue, including fish skeletal muscle. Their data on crude lipid extracts, calculated by a balance of certain analytical values, are of interest for comparison with those of Katada *et al.* For salmon (species not stated) and cod respectively, the values were approximately: total phospholipids, 1·3 and 0·85 per cent; phosphatidyl choline, 0·76 and 0·66 per cent; "cephalin" (i.e. phosphatidyl ethanolamine plus phosphatidyl serine), 0·56 and 0·10 per cent; sphingomyelin, nil and 0·10 per cent; cerebrosides, 1·2 and 0·53 per cent; total cholesterol, 0·04 and 0·05 per cent. It will be seen that their values for cerebrosides are far higher than those of Katada *et al.*

Working with flesh lipids of haddock (*Gadus aeglefinus*), purified by the method of Folch *et al.* (8) and then fractionated by counter-current distribution, Olley and Lovern (10) found that reducing sugar and "sphingo-

TABLE I

Content of certain lipids in the flesh of a tuna[1]

Tissue	*TPL*	*PC*	*PE*	*PS*	*Sph.*	*Cer.*	*Chol.*
Dorsal							
A, I	0·65	0·17	0·12	0·10	0·24	0·17	—
A, E	0·91	0·32	0·19	0·13	0·24	0·26	—
M, I	0·62	0·17	0·13	0·09	0·21	0·17	0·07
M, E	0·88	0·33	0·18	0·10	0·24	0·22	0·07
P, I	0·45	0·12	0·10	0·06	0·16	0·10	—
P, E	0·79	0·33	0·13	0·08	0·23	0·20	—
Ventral							
A, I	1·42	0·59	0·39	0·18	0·21	0·27	—
A, E	1·47	0·64	0·26	0·25	0·25	0·25	—
M, I	1·94	0·64	0·50	0·19	0·15	0·39	0·13
M, E	0·89	0·44	0·20	0·15	0·08	0·19	0·05
P, I	0·50	0·28	0·07	0·07	0·06	0·13	—
P, E	0·64	0·35	0·09	0·10	0·09	0·21	—
Dark muscle							
A, I	1·61	0·56	0·22	0·41	0·38	0·24	—
A, E	2·67	0·95	0·54	0·49	0·67	0·47	—
M, I	1·76	0·69	0·24	0·24	0·56	0·38	0·28
M, E	1·47	0·60	0·28	0·22	0·38	0·42	0·14
P, I	1·67	0·49	0·35	0·30	0·50	0·40	—
P, E	1·06	0·36	0·17	0·20	0·29	0·29	—

[1] Values expressed as g./100g. fresh tissue and rounded off from data of Katada *et al.* (7). Abbreviations of column headings: TPL = total phospholipids, PC = phosphatidyl choline, PE = phosphatidyl ethanolamine, PS = phosphatidyl serine, Sph. = sphingomyelin, Cer. = cerebrosides, Chol. = cholesterol. Abbreviations of tissue portions: A = anterior, M = middle, P = posterior, I = internal, E = external.

sine" (really chloroform-soluble nitrogen in the assay procedure of McKibbin and Taylor (11)) were indeed present in certain fractions, but that their distribution did not run parallel. The highest content of reducing sugar was found in a sphingosine-free fraction. These authors would not commit themselves therefore to any estimate of the content of sphingolipids in haddock flesh. It is only fair to add at this point that Katada (12) fractionated the sphingolipids which he obtained from tuna flesh by chromatography on silicic acid. In addition to sphingomyelin he obtained seven distinct fractions of varying hexose and sphingosine content. No analyses are given for fatty acid content, but the yields of hexose and sphingosine are of the right order for the cerebroside types Katada postulates.

Katada *et al.* (13) also studied the phospholipids of the flesh of the herring (*Clupea pallasii*). With preparations purified by the washing procedure of Folch *et al.* (8) they found the compositions given in Table II. Male and female fish were examined separately, but showed no notable differences in flesh lipids; the results are accordingly averaged in Table II. Katada *et al.* also found about 0·01 and 0·05 per cent of plasmalogens in ordinary muscle and dark muscle respectively. As might be expected, the similarity in male and female lipid composition did not extend to the gonads (roe).

Comparison of Tables I and II shows that in both species the dark muscle is richer in lipids than the ordinary muscle. This is, indeed, a general finding by other workers with diverse species. It applies to triglycerides also; e.g. Katada *et al.* found 2·6 per cent of triglyceride fat in the ordinary flesh and 16·5 per cent in the dark flesh of the same fish. It is difficult to assess mean values for the tuna lipids, in the absence of data on the weights of the various tissues examined. But herring dark muscle is outstandingly rich in total phospholipids, phosphatidyl choline and phosphatidyl ethanolamine.

Recent work in which purified lipid extracts of fish flesh have been fractionated on silicic acid columns has given a consistent picture. The data of Lovern *et al.* (14) on cod (*Gadus callarias*), of Bligh (15) on the same species, and of Gray and Macfarlane (16) on rainbow trout

TABLE II

Content of certain lipids in the flesh of the herring[1]

Tissue	*TPL*	*PC*	*PE*	*PS*	*Sph.*	*Cer.*	*Chol.*
Ordinary muscle . .	0·94	0·50	0·22	0·14	0·06	0·17	0·08
Dark muscle . .	2·58	1·43	0·65	0·35	0·12	0·45	0·25

[1] Values expressed as g./100 g. fresh tissue and rounded off from data of Katada *et al.* (13). Abbreviations of column headings: TPL = Total phospholipids, PC = phosphatidyl choline, PE = phosphatidyl ethanolamine, PS = phosphatidyl serine, Sph. = sphingomyelin, Cer. = cerebrosides, Chol. = cholesterol.

TABLE III

Composition of the phospholipids of the flesh of cod and rainbow trout

(as per cent of total phospholipids)

Species	*PC*	*PE*	*PS*	*PI*	*PX*
Cod (14) . .	67	23	2	1	7
Cod (15) . .	64	23	10		3
Trout (16) . .	67	21	4	2	4

Note 1. PC = phosphatidyl choline plus choline plasmalogen, PE = phosphatidyl ethanolamine plus ethanolamine plasmalogen, PS = phosphatidyl serine plus any serine plasmalogen, PI = phosphatidyl inositol, PX = cardiolipin, polyglycerol phospholipids and unknowns of similar chromatographic distribution.

Note 2. Trout flesh phospholipids also contain 2 per cent of sphingomyelin. This compound was not directly determinable from the cited data on cod flesh, but is certainly only a very minor component in the samples studied.

Note 3. Trout flesh phospholipids contain about 2 per cent ethanolamine plasmalogen and less than 1 per cent choline plasmalogen. Haddock flesh lipids (10) contain about 2 per cent plasmalogens and those of cod flesh are similar.

(*Salmo iridius*) are given in Table III. Bligh's results have been calculated by enlarging the figures reproduced in his preliminary note and measuring the areas under the various peaks. All these workers assessed the total phospholipid content of the flesh of these species as within the same approximate range, viz. 0·6 — 0·7 g./100 g. of the fresh tissue.

Examination of the flesh lipids of cod and haddock by counter-current distribution gives a slightly different picture from that obtained chromatographically. Thus the former technique (10, 17) suggested the presence of some 15–20 per cent of unidentified phospholipids in the total mixture. Some of this would be polyglycerol phospholipids; but some apparently accompanied phosphatidyl choline and phosphatidyl ethanolamine during chromatography (14). Counter-current distribution further suggested that the inositol lipids of cod and haddock flesh consisted of more than one type of compound, and might total more than the amount found chromatographically in cod phospholipids (viz. 2 per cent for cod and 4 per cent for haddock). Incidentally the chromatographic data leave little room for cerebrosides.

The cholesterol content of cod (17), haddock (10) and rainbow trout (16) flesh has been reported as 0·07, 0·05 and 0·05 g./100 g. respectively. Some 75 per cent is free, the rest esterified. The position with other species seems to be very similar.

While there are fluctuations in total phospholipid content both within one fish (7) (18) and from individual to individual within a species, these are of a relatively minor nature. For 16 cod the phospholipid content of the whole skinned fillet was 495 ± 50 mg./100 g. (19). Similarly small standard deviations have been noted by Chang *et al* (20) for sockeye salmon (*Oncorhynchus nerka*), particularly when all were in the same stage of the spawning run. Thus, the flesh of salmon at the commencement and finish of the spawning run contained the following proportions of total phospholipids (lipid phosphorus × 25) in mg./100 g.: male fish, 727 ± 38 and 715 ± 40 respectively; female fish, 690 ± 89 and 595 ± 6 respectively.

TABLE IV

Total phospholipids in the flesh of various species of fish[1]

Species	*Amount*
Angler fish (*Lophius piscatorius*) .	408, 480
Dab (*Limanda limanda*) . .	585
Dogfish (*Squalus acanthias*) . .	553, 625, 628, 793, 880, 910
Gurnard (*Trigla gurnardus*) . .	645, 670, 720
Hake (*Merluccius merluccius*) . .	570
Halibut (*Hippoglossus hippoglossus*) .	564, 565, 575, 587, 690
Herring (*Clupea harengus*) . .	722, 775, 780, 815
John Dory (*Zeus faber*) . .	562, 580
Lemon Sole (*Microstomus kitt*) .	510, 535
Ling (*Molva molva*) . . .	457, 485, 505
Lingcod (*Ophiodon elongatus*) .	578, 578, 597
Megrim (*Lepidorhombus whiffiagonis*)	550
Nursehound (*Scyllium canicula*) .	465, 503
Saithe (*Gadus virens*) . . .	685, 750
Skate (*Raja maculata*) . . .	487, 500, 590, 635
Witch (*Glyptocephalus cynoglossus*) .	475, 500

[1] As mg./100 g. fresh tissue. Data on lingcod from Tomlinson *et al.* (21), others from Olley (19).

Data on numerous other species examined by adequate lipid extraction and purification processes are given in Table IV, and may be compared with the values quoted in Tables I and II for tuna and herring species and in the text for cod, salmon and trout. In considering the data in Table IV it is necessary to remember that dark muscle was not separated and that the proportion of this to ordinary muscle varies with species. Nor were the various samples biologically uniform, e.g. for sex, season, etc. The variations from fish to fish within a species can clearly be greater than those noted above for cod, the dogfish being an outstanding example. Similarly, variation by species can be appreciable. But compared to the well-known large variations in triglyceride fat in fish flesh, either from species to species or often within a species, fish flesh phospholipids do correspond pretty well to Terroine's idea of an "élément constant".

In conclusion of this section some preliminary data may be given on the distribution of non-depot lipids at the sub-cellular level in the fish flesh. Work with cod at the Torry Research Station, Aberdeen, by Miss D. Young (22), has indicated that about 55 per cent of the non-depot lipids are present in the myofibrils, about

30 per cent in the large granules and about 5 per cent in the small granules. The remaining 10 per cent is found in the supernatant fluid on differential centrifugation. The actual lipid contents of these cellular components are quite different from the proportions of the total lipid present in them. Thus myofibrils prepared according to the method of Perry and Grey (23) contained only 2·6 per cent of lipids, calculated on the protein present at N × 6·25. But myofibrils make up most of the cellular substance. By contrast, the large and small granules contained about 30 per cent and 60 per cent of lipids respectively. Qualitatively at least, the lipids from all of these fractions, including the supernatant liquid on centrifuging, were a very similar mixture.

1.3. Composition of some individual lipids in fish flesh. Fish depot lipids are, in comparison with the depot lipids of land animals, remarkable for the complex mixture of their component fatty acids. Typically these range in chain length from 14 to 22 carbon atoms and include numerous highly-unsaturated compounds. Actually this characteristic assortment of fatty acids appears to depend on the food supply, and it should be noted that similar mixtures of fatty acids occur in aquatic invertebrates (see below), including the vegetable-feeding plankton crustaceans. The fats of freshwater fish and marine fish respectively fall into two broad classes, probably as a direct result of dietary factors (24) (25). Apart from these general types, certain species of fish deposit lipids containing a considerably different assortment of fatty acids from those in their diet. Most of the examples of this will be found in a later section of the report, but attention may be drawn to the earlier mention of alkoxydiglycerides and wax esters in fish flesh. These lipids are different from ingested fat.

Far more information is available on the fatty acids of the depot lipids than of the non-depot lipids. Indeed, there is such a volume of data on the former that only a selection can be given. Until recently, the component fatty acids of natural fats, including fish fats, were usually analysed solely by fractional distillation of the mixed methyl esters. Most of the available data on the fatty acids of fish fats have been obtained in this way. Such a technique is incapable of adequately separating fatty acids of the same chain length but of varying level of unsaturation. Hence the analyses performed solely by this method are expressed in terms of mean unsaturation for each group of unsaturated acids of the same chain length. Saturated acids can be determined fairly readily, and so have always been given separately. As an example, an expression like "C_{20}(2·9)" or "C_{20}(− 5·8H)" would indicate a group of acids, all

TABLE V

Some component polyunsaturated acids of herring and menhaden body oils[1]

Acid	*Herring*	*Menhaden*
C_{16}-dienoic	52% 9, 12-diene 14% 6, 9- „ 7% 7, 10- „	80% 9, 12-diene 20% 6, 9- „
C_{16}-trienoic	70% 6, 9, 12-triene 11% 7, 10, 13- „ 6% 4, 7, 10- „ 6% 9, 12, 15- „	83% 6, 9, 12-triene 17% 7, 10, 13- „
C_{16}-tetraenoic	70% 6, 9, 12, 15-tetraene 20% 4, 7, 10, 13- „	95% 6, 9, 12, 15-tetraene 5% 4, 7, 10, 13- „
C_{18}-dienoic	Mainly 9, 12-diene	80% 9, 12-diene 20% 6, 9- „
C_{18}-trienoic	Mainly 9, 12, 15-triene	80% 9, 12, 15-triene 20% 6, 9, 12- „
C_{18}-tetraenoic	6, 9, 12, 15-tetraene	6, 9, 12, 15-tetraene
C_{20}-dienoic	11, 14-diene	50% 7, 11-diene 50% 11, 14- „
C_{20}-trienoic	8, 11, 14-triene 11, 14, 17- „	50% 5, 8, 11-triene 50% 8, 11, 14- „
C_{20}-tetraenoic	5, 8, 11, 14-tetraene 8, 11, 14, 17- „	60% 8, 11, 14, 17-tetraene 40% 5, 8, 11, 14- „
C_{20}-pentaenoic	5, 8, 11, 14, 17-pentaene	5, 8, 11, 14, 17-tetraene
C_{22}-pentaenoic	7, 10, 13, 16, 19-pentaene	7, 10, 13, 16, 19-pentaene
C_{22}-hexaenoic	4, 7, 10, 13, 16, 19-hexaene	4, 7, 10, 13, 16, 19-hexaene

[1] Data from refs. 26, 28 and 34. Percentages given for herring oil are minimal contents. When only one isomer is reported it is certainly the main one, but the absence of small amounts of other isomers should not be assumed.

with 20 carbon atoms, and mean unsaturation 2·9 double bonds. The latter mode of expression has been used in almost all published work on fish lipids. In modern terminology it is more usual to express unsaturation in terms of double bonds than in terms of lack of hydrogen, but this would have been unsafe in the days before the structure of the acids was known. Some of the unsaturation might well have been acetylenic. In the present paper, unsaturation will be expressed as average number of double bonds.

Recently, by the use of such techniques as column chromatography, paper partition chromatography, gas-liquid chromatography and counter-current distribution, it has been possible to subdivide the various homologous groups obtained by fractional distillation. It has further been possible to detect the presence of traces of acids with an odd number of carbon atoms. Previously these had been detected by repeated large-scale fractional distillation in the liver fat of one species of shark (see below). Probably they are of widespread occurrence in fish lipids, but have been missed in the usual fractional distillation procedures.

As examples of the complexity of fish flesh lipids, some recent data on herring oil and menhaden oil are given in Table V. It will be seen that the unsaturated C_{16} acids of herring oil are claimed to contain at least 12 components, made up of various isomers of monoenoic, dienoic, trienoic and tetraenoic acids (26). In menhaden oil eight components have been characterized in this one group of acids (27). Menhaden oil has been found to contain at least 23 unsaturated acids in a total of over 44 component acids (28). Included in these are small proportions (0·05, 0·60, 0·65 and 0·09 per cent, respectively, in the sample examined) of saturated acids with 13, 15, 17 and 19 carbon atoms (29).

Although such detailed data are very instructive and emphasize the great complexity of fish fats, it must not be forgotten that the relative proportions of these components will be considerably different in different samples from the same species. Thus herring oil is known to vary widely in composition according to the season of the year and the type of food ingested (30). Hence it would be unwise to attach too great a significance to all the quantitative aspects of the data in Table V. Some features appear to be a general finding. Within most homologous groups the most highly unsaturated of the polyenes is the most plentiful, viz. C_{18}-tetraene, C_{20}-pentaene, C_{22}-hexaene. (C_{16}-polyenes are an exception.) The multiple unsaturation is invariably of the methylene-interrupted type; never conjugated and never with more than one methylene group between the double bonds. The individual isomers and their relative proportions are very similar in the two oils. The characteristic polyenes of terrestrial plant and animal life (namely linoleic and linolenic acids) are present only in traces. Indeed, feeding tests on rats deficient in "essential fatty acids" have shown that both linoleic and arachidonic acids, as well as any acid which could substitute for these, are present only to about 2 per cent of the total in the flesh lipids of herring, menhaden and tuna (31). This agrees with earlier work on herring and menhaden flesh oils and on the liver oil of the cod (32). The greater part of the polyenoic acids of fish fats belong to Klenk's (33) "linolenic series", when their unsatura-

TABLE VI

Examples of variation in fatty acid composition in fish flesh lipids due to biological and dietary influences[1]

Fish	*Sample*	*Saturated acids*			*Unsaturated acids*				
		C_{14}	C_{16}	C_{18}	C_{14}	C_{16}	C_{18}	C_{20}	C_{22}
Herring (30) . (*Clupea harengus*)	(a)	8·0	15·7	0·2	—	4·6 (1·3)	22·2 (1·4)	22·0 (1·9)	27·3 (2·1)
,,	(b)	8·3	12·1	0·3	0·5	6·4 (1·7)	21·0 (2·2)	28·3 (2·7)	23·1 (2·3)
Trout (41) . . (*Salmo trutta*)	(c)	3·1	19·1	4·5	0·4	11·5 (1·3)	38·3 (1·9)	15·0 (3·9)	8·2 (5·0)
,,	(d)	2·2	17·0	4·0	0·1	8·8 (1·2)	26·3 (1·5)	19·7 (3·3)	19·0 (4·6)
Salmon (42) . (*Salmo salar*)	(e)	2·7	17·7	3·3	3·1	21·7 (1·1)	30·0 (1·9)	12·9 (4·1)	9·9 (5·1)
	(f)	2·7	14·3	5·0	0·7	7·9 (1·0)	32·2 (1·6)	19·4 (3·3)	17·8 (4·7)
	(g)	2·3	13·2	1·0	—	4·3 (1·0)	27·3 (1·3)	25·8 (2·6)	26·1 (3·9)

[1] Values expressed as present by weight of the total acids. Mean unsaturation values, as average number of double bonds, in parentheses. Samples as follows: (a) lean fish caught in April, (b) fatty fish caught in July after intensive feeding, (c) non-migratory form, (d) migratory form, (e) young fish at "parr" stage, (f) young fish at "smolt" stage, (g) male fish after spawning.

tion is considered relative to the terminal methyl group rather than to the carboxyl group.

It is noteworthy that the polyunsaturated fatty acids of the depot lipids in the flesh of other species appear to contain the same major isomers. Thus, S. African pilchard oil contains the same C_{16}-tetraene (35), C_{18}-tetraene (36), C_{20}-pentaene (37) and C_{22}-hexaene (38) as the predominant forms in herring and menhaden oils. The same C_{22}-hexaene has also been found in the flesh oils of tuna (39), and of the Japanese mackerel-pike (*Cololabis saira*) (40). Japanese sardine (*Clupanodon melanostica*) oil contains a C_{20}-5, 8, 11, 14-tetraene (40). A difference from herring and menhaden is claimed for the C_{22}-pentaenoic acid of Japanese mackerel-pike (40), where the main component appears to be the 4, 7, 10, 13, 16-isomer.

Even if the data were available, it would be difficult to tabulate quantitative fatty acid compositions for numerous fish lipids based on over 40 component acids. Since variation in the relative proportions is, moreover, certain to occur, there will continue to be a use for tabulations of the type derived from simple ester distillations. A selection of these is given in Tables VI, VII and VIII. Table VI illustrates the extent of the variation that may exist with a species; Table VII lists the fatty acid compositions of some representative flesh depot lipids; and Table VIII that of some flesh non-depot lipids. Various trace components, and occasionally minor components, have been omitted from these tabulations. A dash indicates that the acid in question was either absent or present in such low concentration that it was not detected. Admitting the inevitability of variation, as well as experimental inaccuracy, numerical values in fatty acid composition tabulations have been approximated to the nearest whole numbers from Table VII onwards.

The characteristic differences between the lipids of freshwater and marine animals are the greater proportions of C_{16}- and particularly C_{18}- unsaturated acids, and the lesser proportions of C_{20}- and particularly

TABLE VII

Fatty acid compositions of some fish flesh depot lipids[1]

Fish	*Saturated acids*			*Unsaturated acids*				
	C_{14}	C_{16}	C_{18}	C_{14}	C_{16}	C_{18}	C_{20}	C_{22}
Menhaden (43) (*Brevoortia tyrannus*)	7	17	3	trace	15 (1·7)	22 (1·7)	20 (3·8)	11 (5·8)
Sprat (44) (*Clupea sprattus*)	6	19	1	trace	16	29 (1·4)	18 (2·8)	11 (3·5)
Pilchard (45) (*Sardina ocellata*)	7	17	2	2	15 (1·6)	19 (1·9)	26 (4·4)	11 (4·5)
Carp (44) (*Cyprinus carpio*)	4	15	2	1	18	46 (1·6)	15 (3·4)	—
Pollan (44) (*Coregonus pollan*)	3	14	2	1	20	40 (1·6)	14 (3·7)	6 (4·5)
Castor-oil fish (4, c) (*Ruvettus pretiosus*)	—	3	—	—	—	75 (1·0)	3 (1·0)	1 (1·0)

[1] Expressed as in Table VI. Unsaturated C_{14}-acids and C_{16}-acids mainly monoethenoid. The lipid from the castor-oil fish is entirely composed of wax esters. In addition to the acids listed it contains 13 per cent of a hydroxy-oleic acid.

TABLE VIII

Fatty acid compositions of some non-depot lipids from fish flesh[1]

Fish	*Lipid*	*Saturated acids*			*Unsaturated acids*				
		C_{14}	C_{16}	C_{18}	C_{14}	C_{16}	C_{18}	C_{02}	C_{22}
Haddock (46) (*Gadus aeglefinus*)	Triglycerides	Trace	14	7	—	14	26 (2·0)	26 (3·5)	13 (5·4)
,,	Cholesteryl esters	—	8	6	—	—	20 (1·7)	29 (3·0)	37 (3·9)
,,	Lecithins	—	18	7	—	—	14 (2·1)	35 (3·6)	24 (5·4)
Trout (16) (*Salmo iridius*)	Lecithins	2	26	3	—	3 (1·0)	13 (1·1)	11 (4·5)	42 (5·9)
,,	Cardiolipin	2	19	13	—	4 (1·0)	51 (1·1)	—	2 (5·0)

[1] Expressed as in Table VI. Unsaturated C_{16}-acids of haddock triglycerides are mainly monoethenoid.

C_{22}- unsaturated acids in the freshwater organisms (41). Examples of this effect within a species can be seen in Table VI. The non-migratory form of *Salmo trutta* spends its entire life in freshwater, the migratory form feeds heavily in the sea. Salmon parr live only in freshwater. The adult salmon feeds only in the sea. (The changes in salmon fat in the parr-smolt metamorphosis are probably due to non-dietary factors). Further examples involving different species are given in Table VII, carp and pollan being freshwater species, the others marine. The castor-oil fish is included for its biochemical interest.

While the data in Tables VI and VII may be taken as representative of the great majority of fish flesh depot lipids (at least of Teleostean fish; data on Elasmobranch flesh lipids are lacking), it will be seen from Table VIII that the non-depot lipids present a different picture. Stearic acid seldom amounts to more than a few per cent of the total acids of fish depot lipids, but may be more important in some of the non-depot lipids. At the other end of the saturated acid series, myristic acid, practically a universal minor component of the depot lipids, may be absent from some non-depot lipids. Among the unsaturated acids, the total absence of C_{14}-compounds and the marked reduction in C_{16}-compounds in some non-depot lipids may be noted, together with the sometimes unusually high proportions of C_{22}-compounds in non-depot lipids. Trout cardiolipin is outstanding in its marked lack of longer chain acids and its low level of unsaturation. Far more data on non-depot lipids are required before a representative picture of their characteristic compositions can be formed.

In those fish lipids which are partly or entirely wax esters, the higher aliphatic alcohols are typically mainly of 16 and 18 carbon atoms, with unsaturation largely confined to a monoethenoid C_{18}-alcohol. Thus in *Ruvettus pretiosus* flesh lipids the alcohols consist of 50 per cent hexadecanol, 6 per cent octadecanol and 44 per cent octadecenol (4c), and in *Xenogramma carinatum* they contain about 60 per cent hexadecanol and 35 per cent octadecenol (5).

Before leaving this section it may be of interest to note the detailed composition of the mixture of aldehydes released from the ethanolamine-plasmalogen of trout flesh (16). Gas chromatography of their dimethyl acetals gave the following proportions (as percentages of the total aldehydes) of various compounds: (i) saturated aldehydes, straight chain; C_{15} 11·0, C_{16} 66·5, C_{17} trace, C_{18} 3·7, C_{20} trace; (ii) saturated aldehydes, branched chain; C_{15} 0·5, C_{17} 4·3, C_{19} 3·4. Only one unsaturated aldehyde was found, *viz.*, the straight chain C_{18}-monoethenoid compound, amounting to 10·7 per cent.

2. The visceral lipids of vertebrate fish

Fish often use one of the internal organs as a lipid depot. In many species the liver is so used, and 75 per cent or more of its fresh weight may be lipid. In other species fat is stored in the mesenteric or peritoneal membranes and in a few cases in the ovaries.

Fish visceral lipids are of nutritional significance. In some cases the organs are consumed as human food (e.g. roe and liver), or the lipids are used medicinally (e.g. fish liver oils). In other cases the viscera, either as such or as part of the whole fish, are used in making fish meal for animal use. Quantitatively, only the liver and roe are likely to be important and, as it happens, far more data are available on the lipids of these organs than of others. This section will, therefore, largely be concerned with fish liver and roe.

2.1. Depot lipids in fish viscera. The significance which will be attached to the word "depot" is similar to that in section 1.1, except that the critical level must be raised somewhat from 1 per cent. The content of phospholipids, sterols, etc. in viscera is often as high as 5 per cent or so of the fresh weight. Lipid contents appreciably in excess of this will be taken as evidence of the presence of depot lipids.

As with flesh depot lipids, triglycerides are the most widely distributed type of visceral depot lipid. However, among the Elasmobranch fishes, alkoxydiglycerides are of common occurrence. All such fish have large, oil-rich livers, even when they also use the flesh as a major depot (e.g. in *Squalus acanthias*, where the liver may amount to 10 per cent or more of the live weight and contain up to 75 per cent of lipid). In many Elasmobranchs the liver depot lipids consist only of triglycerides, e.g. in the thresher shark (*Alopoecia vulpes*) or the skate (*Raia maculata*). In others (e.g. *Squalus acanthias*) a mixture of alkoxydiglycerides and triglycerides is found, while in yet other species alkoxydiglycerides may compose the whole of the lipid (e.g. at times in the ratfish, *Chimaera monstrosa*). In still another group of Elasmobranch fish, the hydrocarbon "squalene" forms a part of the liver depot lipids. Squalene is not a "lipid" according to the definition given in the introduction; but it is biogenetically related to an undoubted class of lipids, the sterols, and it certainly seems to function as an energy reserve lipid in these fish. Squalene is typically accompanied by alkoxydiglycerides, while triglycerides may or may not be present also. Squalene, a well-known dihydrotriterpene with six double bonds, $C_{30}H_{50}$, is always accompanied by smaller proportions of two other hydrocarbons, namely "pristane" (2, 6, 10, 14-tetramethylpentadecane) (47) and "zamene", an unsaturated analogue of pristane with a double bond between carbons 1 and 2 (48). The ratios of squalene and of alkoxydiglycerides to each other and to triglycerides can vary widely, even within a species. Thus the liver oil of the basking shark has been reported (3c) (49) to contain from 7–45 per cent of squalene and 2–7 per cent of pristane, the balance being mainly triglycerides. Again, that of the ratfish (50) may contain from about 30 per cent to almost 100 per cent of alkoxydiglycerides, with a squalene content ranging from virtually nil to about 60 per cent. Such variation makes nonsense of any attempt to tabulate precise data on the overall lipid composition of many Elasmobranch fish and a descriptive account, such as the present, is less likely to be misleading.

It should be noted that squalene and its companions are not confined, as major components, to liver tissues. Thus they have been found in shark egg (51) and stomach lipids (52).

Wax esters do not appear to be common major components of fish liver lipids, although in trace amounts they must be widespread, since higher aliphatic alcohols are common components of the 1 per cent or so of unsaponifiable matter obtained from fish depot lipids. They occur in larger proportions, however, in the liver lipids of at least two Japanese species, viz. *Lotella phycis* (53) and *Laemonema morosum* (54), in each of which about 20–30 per cent of higher aliphatic alcohols has been found. Waxes may also form an important proportion of the total lipids of the ovaries of some fish. The outstanding example of this is the grey mullet, *Mugil japonicus*, the dried and salted ovaries of which are a greatly esteemed Japanese food. The product as eaten contains some 25–30 per cent of lipids, of which nearly 90 per cent is wax esters, the remainder being triglycerides (55). The ovaries of the globefish, *Spheroides porphyreus*, contain about 30 per cent of oil, which itself contains about 5–10 per cent of wax esters (56).

Before leaving this section, it should be noted that a most unexpected lipid may form one of the most abundant individual components of the visceral lipids of some fish. This is vitamin A and its esters. In such fish as the halibut, containing about 20 per cent of total lipids in the liver, it is possible for this lipid to contain up to 10 per cent of vitamin A (57a). Since this vitamin is almost all in the esterified form, the esters amount to about 4 per cent of the liver weight. In other tissues, e.g. portions of halibut intestinal tract, the total lipid (about 2–5 per cent of the fresh tissue) may contain up to 60 per cent of vitamin A esters (57b, c). The total vitamin A content of a large halibut may be as much as 90 g. and the enormous and rapid seasonal variations suggest that its esters may fairly be regarded as a depot lipid.

In some other species of fish both vitamins A and D are accumulated in amounts far beyond those normally associated with vitamin requirements, and may then form a very high proportion of the lipids of such tissues as liver or intestine.

2.2. Non-depot lipids of fish viscera. The same qualification about inadequate extraction and analytical techniques, as was made above for published data on the non-depot lipids of fish flesh, applies to most data on the visceral lipids. Much of the information has been summarized elsewhere (58). Fish liver has been variously reported to contain from less than 0·2 per cent of total phospholipids to 3·5 per cent of lecithin alone. The lowest values certainly represent incomplete extraction. It is claimed (59) that in at least one species, the Japanese sardine (*Clupanodon melanostica*), the liver content of lecithin varies with the total fat content, according to the nutritional status of the fish, from about 0·7 per cent to about 3·6 per cent of the fresh tissue. The sterol content of fish liver varies with the nutritional and biological status of the fish, e.g. values from 0·50 to 1·42 per cent have been found for the pike, *Esox lucius* (60). This sort of range seems to cover many species, judging by fragmentary data on various fish liver oils. The eggs of a salmon (*Oncorhynchus keta*) have been reported to contain about 1·3 per cent of lecithin, together with much smaller amounts of other glycerophosphatides and sphingolipids (61).

Some quite detailed data have been published on the content of lecithin, cephalin, sphingomyelin, cerebrosides and cholesterol in the brain and spinal cord of numerous species of fish (62), but in view of the small relative size of these organs their nutritional significance is negligible.

2.3. Composition of some individual lipids in fish viscera. The fatty acid composition of depot triglycerides in fish viscera is very similar, both qualitatively and quantitatively, to that of the flesh depot triglycerides already discussed. There is a dearth of studies by modern methods on the structure of the component polyethenoid acids of fish visceral lipids, but it seems probable that they are generally similar to those of fish flesh lipids. Thus Klenk and Bongard (63a) showed that early work, which suggested the presence of an ethylene-interrupted type of unsaturation, was incorrect and that in at least two fish liver oils, namely those of cod (*Gadus callarias*) and skate (*Raia batis*), all the polyenoic unsaturation was methylene-interrupted. The C_{20}-pentaenoic acid of cod liver oil has been shown to be the 5, 8, 11, 14, 17–isomer (63b) (compare Table V). Nutritional evaluation of cod liver oil (32) has shown the same very low content

TABLE IX

Some trace and minor component acids of the liver fat of the school shark (*Galeorhinus australis*, MacLeay)(64)

Type	*Chain length and structure*	*Concentration (% of total acids)*
Straight chain	*n*-pentadecanoic	0·28
„	*n*-heptadecanoic	0·17
„	*n*-pentadecenoic	0·018
„	*n*-hepta-9-enoic	0·073
„	*n*-nona-11-enoic	0·042
„	*n*-nona-10-enoic	0·007
„	*n*-nona-12-enoic	0·008
Branched chain (*iso*-series)	13-methyl-tetradecanoic	0·1–0·2
„	15-methyl-hexadecanoic	0·1–0·2
Branched chain (*anteiso*-series)	12-methyl-tetradecanoic	0·11
„	14-methyl-hexadecanoic	0·18
Multibranched	dimethyl-hexadecanoic	?

TABLE X

Variation in the fatty acid composition of cod liver oil[1]

Sample	*Saturated acids*			*Unsaturated acids*				
	C_{14}	C_{16}	C_{18}	C_{14}	C_{16}	C_{18}	C_{20}	C_{22}
1 (65)	6	8·5	0·5	trace	20 (1·1)	29 (1·4)	26 (3·0)	10 (3·4)
2 (65)	3·5	10	—	0·5	15·5	25 (1·4)	31·5 (3·0)	14 (3·2)
3 (65)	5	6·5	trace	0·5	16	31 (1·4)	30·5 (2·5)	10·5
4 (66)	2	14	1	2	10	26 (1·6)	25 (2·7)	20 (3·7)
5 (67)	4	11	1	trace	11	27 (1·2)	27 (2·5)	19 (3·5)

[1] Expressed as in Table V. Unsaturated C_{14}- and C_{16}-acids are mainly monoethenoid.

of acids of the linoleic series as was found for fish body oils.

The liver oil of one species of shark (*Galeorhinus australis*) has been shown (64) to contain a great range of trace and minor components with odd-numbered carbon chains (both saturated and unsaturated), and with branched chains of both the *iso* and *anteiso*-series. The data have been assembled in Table IX. It remains to be seen how general this picture is among both Elasmobranch and Teleostean fishes.

The fatty acid composition of visceral depot lipids may vary with dietary and biological influences, as was shown to be the case for fish flesh depot lipids. This is illustrated for cod liver oil in Table X. This biological variability should always be remembered when considering the results of a single analysis (as are most of those in the literature), which furthermore may have been performed on a sample from one or two fish only.

A representative selection of the numerous species whose visceral fats have been examined is given in Table XI. The first three species are freshwater Teleosts. The low level of C_{22}-acids in all, and of C_{20}-acids in two, can be seen. In the pike, *Esox lucius*, an inhabitant of temperate regions, the generally high level of C_{16}- and

TABLE XI

Examples of the fatty acid composition of visceral triglycerides of fish[1]

Species	*Tissue*	*Saturated acids*			*Unsaturated acids*				
		C_{14}	C_{16}	C_{18}	C_{14}	C_{16}	C_{18}	C_{20}	C_{22}
Catla Buchanani (68)	Liver	1	19	6	trace	7	25 (1·3)	27 (2·4)	9
Leporinus affinis (69)	Mesentery	3	24	8	trace	11 (1·1)	34 (1·3)	14 (2·8)	6 (4·0)
Esox lucius (44)	Mesentery	3	15	trace	1	20	42 (1·7)	15 (3·3)	4 (4·0)
Salmo salar (70)	Ovary	2	13	2	—	10	35 (1·3)	23 (3·8)	15 (5·6)
Conger vulgaris (71)	Peritoneum	2	19	1	—	6	41 (1·1)	18 (2·7)	13 (4·2)
Gadus virens (65)	Liver	6	12	trace	trace	9	30 (1·6)	27 (2·7)	16 (3·6)
Genypterus blacodes (72)	Ovary	—	20	2	—	7	31 (1·5)	29 (3·6)	11 (3·6)
Alopoecia vulpes (73)	Liver	8	11	trace	2	12	19 (1·7)	31 (3·3)	17 (5·2)
Raia maculata (65)	Liver	4	14	—	trace	10	21 (1·6)	33 (3·6)	18 (4·7)
Squatina angelus (41)	Liver	1	17	2	—	6	21 (1·5)	22 (3·0)	31 (5·1)

[1] Expressed as in Table VI. Unsaturated C_{16} acids are mainly monoethenoid. Some oils contain minor proportions of additional acids.

C_{18}-unsaturated acids, mentioned above as another characteristic of freshwater fish, may be noted. The other two freshwater species inhabit warm waters of India and S. America respectively. Their fats tend to be rather less highly unsaturated than those of fish from cooler water, and this is reflected in increased levels of stearic acid.

The salmon, *Salmo salar*, matures its ova while drawing on its store of body fat. During this maturation, the composition of the ova fat alters considerably, especially in the proportion of C_{18}-acids and their mean level of unsaturation. The example given in Table XI is representative of the fully ripe ova.

The next three fish in Table XI are marine Teleosts, and the last three marine Elasmobranchs. It can be seen that, when Elasmobranch fish utilize triglycerides *alone* as a depot lipid, as do these particular species, their component fatty acids closely resemble those of marine Teleosts.

Those Elasmobranch fish which use alkoxydiglycerides as depot lipids, whether alone or mixed with triglycerides or with squalene, show a pronounced tendency to modify their fatty acids compared to the typical marine fish type, i.e. compared to their dietary fat. Unsaturation is greatly reduced, and in extreme cases polyethenoids are completely absent. There is a tendency to incorporate appreciable proportions of a C_{24}-monoethenoid, whereas C_{24}-acids of any kind seldom amount to more than trace components of other fish oils. Stearic acid may amount to more than the usual traces, and arachidic acid, normally virtually absent, may amount to 1 per cent or so of the total acids. In Table XII are given the fatty acid compositions of the liver oils of three Elasmobranchs. The ratfish (*Chimaera monstrosa*) sample examined consisted solely of alkoxydiglycerides. The oil of the shark *Scymnorhinus lichia* contains a large proportion of squalene, the balance being essentially all alkoxydiglycerides. The oil from the dogfish, *Squalus acanthias*, is about 75 per cent triglycerides and 25 per cent alkoxydiglycerides. The composition of the total oil shows that, in fish which accumulate alkoxydiglycerides, even the triglycerides may be modified in the same direction.

TABLE XII

Examples of the fatty acid composition of fish liver alkoxydiglycerides[1]

Species	*Saturated acids*				*Unsaturated acids*					
	C_{14}	C_{16}	C_{18}	C_{20}	C_{14}	C_{16}	C_{18}	C_{20}	C_{22}	C_{24}
Chimaera (50a) *monstrosa*	—	8	7	1	—	3 (1·0)	51 (1·1)	20 (1·4)	8 (1·7)	2
Scymnorhinus (74) *lichia*	1	14	4	1	trace	4 (1·0)	29 (1·0)	11 (1·0)	26 (1·0)	10 (1·0)
Squalus (1) (75) *acanthias*	6	27	3	trace	2 (1·0)	7 (1·1)	26 (1·0)	13 (1·0)	16 (1·0)	—
„ (2) (65)	6	10	3	—	—	9 (1·0)	25 (1·1)	29 (1·6)	12 (2·0)	6 (1·0)

[1] Expressed as in Table VI. *S. acanthias* (1) represents alkoxydiglyceride fraction alone, (2) the total liver oil.

The compounds with which the fatty acids are combined as alkoxydiglycerides are typically composed of ethers of glycerol with C_{16}- and C_{18}-alcohols. The predominant glyceryl ether is always that known as "selachyl" alcohol, which is D-glyceryl-1-octadec-9-enyl ether. The next most abundant component is "chimyl" alcohol, D-glyceryl-1-hexadecyl ether, with somewhat smaller proportions of "batyl" alcohol, D-glyceryl-1-octadecyl ether. Minor proportions of other homologues may be found. Thus Malins (75), by gas chromatography of the aldehydes obtained by oxidation, found the following composition for the glyceryl ethers of *Squalus acanthias* liver oil: selachyl alcohol, 44 per cent; chimyl alcohol, 24 per cent; batyl alcohol, 18 per cent; glyceryl-1-decyl ether, 6 per cent; glyceryl-1-dodecyl ether, trace; glyceryl-1-tetradecyl ether, 1·6 per cent; glyceryl-1-eicosyl ether, trace; glyceryl-1-docosyl ether, 2 per cent. There were also indications of the existence of small amounts of polyethenoid glyceryl ethers, such as were reported by Japanese workers (76).

The wax esters of fish viscera merit further study. The alcohols involved vary with the species. Thus in the ovary wax of the grey mullet (*Mugil japonicus*) they consist largely of hexadecanol (cetyl alcohol), hexadec-9-enol (zoomaryl alcohol) and octadec-9-enol (oleyl alcohol) (4b) (77). In the liver wax of *Lotella phycis*, hexadecanol, eicosanol and docosanol have been identified among the saturated components (53); but the total alcohols were predominantly unsaturated (iodine value about 80). The ovary wax of the globefish (*Spheroides porphyreus*) contains hexadecanol, octadec-9-enol, eicos-11-enol, docosanol and docos-13-enol (56). The alcohols of liver wax of *Laemonema morosum* contain about 50 per cent of an isomer of the last-named compound, namely, docos-11-enol, together with polyenoic alcohols (54b) (78). The fatty acids of these wax esters do not appear to have been studied really quantitatively; but in some cases they are less highly unsaturated than those of fish triglycerides, thus recalling the position in the alkoxydiglycerides. Thus in the globefish waxes the fatty acids (79) contain about 50 per cent of saturated components (mainly palmitic and stearic acids) with oleic acid a major component of the unsaturated acids. Long chain polyenes have not been reported. The fatty acids of *Lotella phycis* waxes contain only 13–14 per cent of saturated components (mainly palmitic plus a little myristic acid), but over 50 per cent of oleic acid (53). On the other hand, the fatty acids of *Mugil japonicus* ovary waxes contain large proportions of polyunsaturated compounds (iodine value of the total acids 179·5 (4b) (77).

Bearing in mind what was said above about inadequate extraction and separation techniques in some of the work on fish phospholipids, and the selective influence of such inadequacy on the fatty acid composition of the fractions finally obtained, the results of analyses of phospholipids from fish visceral tissues are given in Table XIII. The sample from the New Zealand groper (*Polyprion oxygeneios*) was undoubtedly a product of incomplete and selective extraction. Compared to the triglycerides from the same liver, it is notable for its much higher content of C_{20}- and C_{22}- polyenes (8·8 and 4·0 per cent respectively in the triglycerides). The dogfish (*S. suckleyi*) and salmon (*O. keta*) egg lecithins, compared to typical fish depot lipids, are notable for their relatively high content of stearic acid, and in the dogfish for the lack of hexadecenoic acid and the high content of palmitic acid. The depot lipids of *S. suckleyi* eggs, a mixture of some two thirds triglycerides and one third alkoxydiglycerides, have mixed fatty acids containing 13 per cent of hexadecenoic acid and only 10 per cent of palmitic acid (but 7 per cent of stearic acid). Indeed, their whole composition (82) is different from that of the lecithin fatty acids. This relatively high content of stearic acid and relative lack of hexadecenoic acid was noted above for fish flesh phospholipids also (Table VIII). Far more data are necessary, however, on the detailed composition of individual phospholipids from numerous species and tissues, before a fair overall comparison can be made with the depot lipids.

TABLE XIII

Component fatty acids of some fish visceral phospholipids[1]

Species	*Tissue*	*Lipid*	*Saturated acids*			*Unsaturated acids*				
			C_{14}	C_{16}	C_{18}	C_{14}	C_{16}	C_{18}	C_{20}	C_{22}
Polyprion (80) *oxygeneios*	Liver	Mixed phospholipids		← 18 →		—	17	20 (1·2)	31 (3·3)	14
Squalus (81) *suckleyi*	Egg	Lecithin fraction	trace	34	9	—	—	27 (1·7)	13 (4·0)	13 (5·0)
Oncorhynchus (61) *keta*	Egg	„	3	22	9	—	6 (1·1)	36 (1·6)	12 (4·3)	12 (5·0)

[1] Expressed as in Table VI.

3. The lipids of aquatic invertebrates

Aquatic invertebrates will be considered as a composite group, despite the enormous range of zoological classes, families and species involved. Moreover, with few exceptions, the lipids of the entire animals will be discussed, rather than those of individual tissues. This is partly because most of the available data relate to entire animals, and partly because that is the way in which many of them are utilized, either as human or as animal food. Many of the species examined are of biochemical interest rather than of significance in human or domestic animal nutrition, although no doubt all play a part, direct or indirect, in the nutrition of those species of aquatic animal which do have such significance.

3.1. Nature of the lipids of invertebrates. All the types of lipid discussed above for vertebrate fish have been found in one or more groups of invertebrate studied. On the basis of the very fragmentary data available, it would be most unsafe to assume, without proper analytical checking, that the lipids of any invertebrate consist mainly of triglycerides. It would be equally unsafe to assume that the predominant sterol is cholesterol. As a matter of interest, far more investigations have been conducted on the sterols than on the other lipids of aquatic invertebrates, largely because of the enormous variety of sterols thus revealed.

Some of this wealth of literature on the sterols has recently been summarized by Toyama (83) who, with his colleagues, has been responsible for a great part of the investigational work. In his review he lists data on the lipids of some 80 species distributed over the classes of Protochordata, Echinodermata, Arthropoda, Mollusca and Coelenterata. The method of extraction used (drying, powdering and extraction by ether) would inevitably be incomplete. Nevertheless, Toyama's data give a useful general picture.

Toyama's data on lipid content relate to dry weight of tissues, and show values for total lipids ranging from about 1 per cent to 25 per cent for whole animals, or as high as 44 per cent on the separated viscera of the mollusc *Haliotis gigantea*. (Viscera always showed a higher lipid content than the flesh, whenever studied separately). Unsaponifiable matter, usually determined on the acetone-soluble fraction of the lipids, was sometimes quite low (e.g. 5–10 per cent), in which cases it may be assumed that the rest of the acetone-soluble material was predominantly triglycerides. Such predominantly glyceridic lipids were not characteristic of an entire class, or even order, of organisms. Most lipids examined had a high content of unsaponifiable matter (e.g. 20–60 per cent), of which sterols usually made up 30–70 per cent. In such cases it would be unjustifiable to assume that all fatty acids are derived from triglycerides. The derivation of Toyama's values for triglycerides is not clear.

Alkoxydiglycerides and wax esters seem to be of quite widespread occurrence, since the corresponding alcohols have often been reported as major components of the unsaponifiable fraction: e.g. glyceryl ethers in starfish (83), echinoderms (84a), crustaceans (84b) and molluscs (84c), and higher *n*-aliphatic alcohols in sea anemones (84d, e) and crustaceans (84f).

As a point of biochemical interest, it may be noted that some unusual components have been found among the lipids of aquatic invertebrates. Plasmalogens apparently incorporating an acetal structure, instead of the more usual enol-ether structure, have been reported to occur in a sea anemone (*Anthopleura elegantissima*) (85); and non-phosphorylated plasmalogens, corresponding to alkoxydiglycerides with a double bond between carbons-1 and -2 of the aliphatic alcohol radical, in the digestive glands of a starfish (*Asterias forbesi*) (86). (It may be noted that similar non-phosphorylated plasmalogens have recently been reported to occur in the lipids of various tissues of the ox; *viz.* milk fat, beef tallow and ox heart (87)). In most species examined, the plasmalogens of aquatic invertebrates have proved to be exclusively of the usual type, although indications of the existence of minor proportions of other types were noted for three species (88). The last-quoted authors comment that the tissues of some aquatic invertebrates are as rich a source of plasmalogens as is mammalian brain.

Another unusual lipid is the sphingolipid isolated from the sponge *Lissodendoryx isodyctialis* (89), which is claimed to contain sphingosine phosphorylated on carbon-1, acylated on carbon-3, and with the usual amide-linked fatty acid as well. The phosphate is not further esterified. It may be noted that this is the first reported case in recent years of a sphingosine derivative in which the hydroxyl group on carbon-3 is esterified, and that earlier reports of the occurrence of such lipids were incorrect. It is also the first reported case of a sphingosine-based phosphatidic acid. The authors suggest the name "acylsphingomyelin phosphatidic acid". The fatty acids of this novel phospholipid were a singularly complex mixture with chain-lengths ranging from 10 to 22 carbon atoms, although the major ones were palmitic (38 per cent) and hexadecenoic (17 per cent) acids.

Still another novel lipid is the glycolipid found in an oyster, which is claimed to contain only one fatty acid (14-methyl-pentadec-4-enoic acid), esterified to choline. This choline ester forms a salt linkage with the sulphonic group of the amino acid taurine, which in turn is linked to lactic acid and a trisaccharide (2 molecules of D-glucose and one of L-fucose (90)).

Aquatic invertebrates clearly represent a challenging field for the lipid chemist. It is well to repeat a warning given early in this paper. The possibility of post-mortem autolysis must be excluded. In addition, extraction methods, purification techniques and separation procedures must be adequate before a reliable picture of the lipids of these creatures can be obtained. For this reason various reports on the content of individual lipid classes, such as lecithins, "cephalins", cerebrosides and sphingomyelins, will not be quoted.

3.2. Component fatty acids of the lipids of aquatic invertebrates. A sufficient number of analyses have now been published to justify the conclusion that, in general, the component acids of the lipids of aquatic invertebrates

TABLE XIV

Component fatty acids of lipids of aquatic invertebrates[1]

Species	*Type*	*Saturated acids*			*Unsaturated acids*				
		C_{14}	C_{16}	C_{18}	C_{14}	C_{16}	C_{18}	C_{20}	C_{22}
Spisula (91) . . *Sachalinensis*	Mollusc	1	12	4	—	15 (1·2)	34 (2·0)	23 (3·4)	10 (4·3)
Mytilus (92) . . *edulis*	,,	2	17	2	trace	11 (1·2)	21 (2·0)	30 (3·6)	14 (4·6)
Octopus (93) . *dofleini*	,,	2	11	10	1 (1·0)	9 (1·3)	31 (1·9)	23 (3·9)	8
Calanus (84b) . *finmarchicus*	Crustacean	8	11	1	2 (1·0)	12 (1·2)	17 (2·5)	24 (3·9)	25 (4·0)
Daphnia (84f) . *galeata*	,,	3	13	2	3 (>1·0)	21 (>1·0)	45 (2·5)	·12 (4·0)	—
Suberites (94) . . *compacta*	Sponge	trace	7	1	trace (1·0)	3 (1·0)	11 (1·1)	8 (1·1)	18 (3·1)

[1] Expressed as in Table VI. Some of the lipids contain minor amounts of other acids. For further notes on *O. dofleini* and *S. compacta* see text.

closely resemble those of vertebrate fish. These analyses usually relate to the total lipids of the organism. A selection of them is given in Table XIV.

The crustacean *Daphnia galeata* is the only freshwater organism listed. Compared to the other organisms, the effect of its environment can be seen in the high level of C_{16}- and C_{18}-unsaturated acids and the low level of C_{20} and C_{22}-acids (see previous discussion under sections 1.3 and 2.3). *Octopus dofleini* contains some lower fatty acids, including C_8-, C_{10}- and C_{12}- saturated acids, and the following unsaturated compounds: deca-3-enoic acid and dodeca-4-enoic acid. *Suberites compacta*, like another sponge studied at the same time, is remarkable for its content of very long chain acids, *viz.*: C_{24} (3·6), 12 per cent; C_{26} (?), 22 per cent; C_{28} (2·2), 17 per cent. It also contains a 2-hydroxy-tetracosanoic acid. The unsaturation of some of the homologous groups is unusually low, e.g. for the C_{20} acids.

LIPID HYDROLYSIS DURING THE PROCESSING OF FISH

The term "processing" will be taken to include any treatment applied to the fish between catching and retail sale. It will thus include stowage in ice, either aboard the fishing vessel or during subsequent distribution ashore.

The diverse lipids discussed above could, if hydrolyzed at their various linkages, give rise to numerous decomposition products. Broadly these can be placed into two groups: (*a*) water-soluble, and hence non-lipid, fragments (*b*) lipid fragments. Examples of group (*a*) would be glycerol, glycerophosphate, choline, phosphorylcholine, etc. Examples of group (*b*) would be di-and monoglycerides, phosphatidic acids, lysophosphatides, glyceryl ethers, aliphatic alcohols and free fatty acids. Experimental work on lipid hydrolysis in fish tissues has been directed exclusively to studies of the loss of original lipids and of the accumulation of lipid fragments. Although no direct estimations have been made of the accumulation of water-soluble fragments, certain conclusions can be drawn from the nature of the lipid fragments. For example, a fall in lecithin and a rise in phosphatidic acid would involve the liberation of free choline.

As indicated in the opening section, the effects of processing will be considered according to the principles involved. Hence the headings used below relate to the various factors which affect lipid breakdown.

It may be said at the outset that nothing seems to be known of lipid breakdown during the processing of aquatic invertebrates.

4. The effect of micro-organisms

Processing operations may be grouped roughly into those in which micro-organisms multiply and those in which their growth is prevented. Within each of these groups there will be certain differences of degree. Thus, with fish stowed in ordinary ice the only check to microbial growth is the relatively low temperature. With fish stowed in ice containing an antibiotic, in lightly salted fish and in smoked fish, there will be a retardation of microbial growth, selective in nature, additional to any achieved by low temperatures. Microbial activity and growth is prevented at sufficiently low temperatures (e.g. in cold-stored fish) or sufficiently low moisture contents (dehydrated fish, fish meal, etc.), but the products are not sterile. On the other hand, canned fish is virtually sterile.

Micro-organisms of many types are known to produce lipid-splitting enzymes. If a heavy microbial load is picked up before a fish product is kept under conditions which prevent further bacterial growth, but which do not involve destruction of any extra-cellular microbial enzymes which might be present (e.g. freezing and low-temperature drying), microbial influences could still be exerted.

4.1. Effect of micro-organisms on the lipids of fish flesh. While the separate contribution of microbial enzymes to lipid hydrolysis has not been investigated in most types of processed fish, it has been studied in two major groups: (*a*) "wet" fish stowed in ice, (*b*) frozen fish. In both cases it proved to be negligible.

The course of lipid hydrolysis in the flesh of eviscerated whole cod stowed in crushed ice proved to be identical with that in sterile cod flesh stored at 0°C (95). This identical course persisted for at least 4 weeks, which is far beyond the period of edibility and well into the period of advanced bacterial putrefaction. In the flesh of whole herring, stored in ordinary ice and in antibiotic ice respectively, production of free fatty acids followed virtually the same course for up to 3 weeks, despite an enormous difference in bacterial growth (96). There was no measureable hydrolysis of the phospholipids in the flesh of lingcod (*Ophiodon elongatus*) stored in ice for 3 weeks (97), the limit set to edibility by bacterial putrefaction.

The course of lipid hydrolysis in frozen fish is unaffected by preliminary storage of the fish in ice for up to eight days (95b), (98); i.e. it seems to be unaffected by any extracellular bacterial enzymes accumulated during this period.

Rapid fat hydrolysis is well known to occur in the flesh of whole fish, such as herring, menhaden and sardine, kept without refrigeration for reduction to meal and oil. It is, however, impossible from published data to decide how far, if at all, this is due to microbial spoilage. In addition to any enzymes present in the flesh itself, very active enzymes occur in some of the visceral tissues, and the combined effects of autolysis and bacterial attack may soon make the activity of visceral enzymes evident on the flesh lipids. Certainly fat hydrolysis is quite rapid in whole herring treated with sodium nitrite or formaldehyde at levels which markedly reduce bacterial spoilage (99). Such preservatives will, presumably, react also with the tissue enzymes, and quantitative evaluation of their effects on lipid hydrolysis is impossible.

4.2. Effect of micro-organisms on the lipids of fish viscera. As with fish sent for reduction to meal and oil, so with fish livers sent for oil manufacture. Storage of the livers without refrigeration or other preservative measure leads to putrefaction accompanied by extensive hydrolysis of the oil. But the livers of many species of fish contain a lipolytic enzyme (see below), and it is impossible from published data (e.g. those of Drummond and Hilditch (100, p. 80) to disentangle the separate effects of this enzyme and of microbial enzymes. Preservatives sometimes used or advocated for use with fish livers (101) are known also to inhibit or destroy tissue lipase. This effect is actually exploited in one patented process (101b) in which the action of fish liver lipase is inhibited, together with bacterial growth, while the liver proteinases remain active. Even such mild bacteriostatic agents as the vapour of chloroform or toluene, widely used in enzyme studies, have been found to produce gradual inhibition of the lipolytic enzymes in fish tissues (95b).

5. The effect of heat

In considering the effect of heat, it is not intended in this section to consider the effect of storage temperature. This aspect is discussed in a later section. What is considered here is the effect of a specific heat treatment, such as cooking, on the lipids of fish. Changes produced by heat must always be related both to temperature and to time.

It has been shown that heating to 100°C for periods of up to 90 minutes does not produce any detectable simple chemical hydrolysis of the lipids in fish tissues. This is true even for the readily-hydrolysable phosphoglycerides of fish flesh (95b), and it is well known that steam-rendering of fresh livers gives a virtually neutral oil. This is true even when the process is prolonged for 60 minutes (100, p. 87).

Heat treatment which will denature proteins will ultimately denature enzymes also. But since different proteins have different stabilities towards heat, it is clearly unsafe to assume that in fish adequately cooked by organoleptic standards all enzymatic activity is suppressed. In fact, it has been found that cooking of cod fillets for 30 minutes in a casserole surrounded by steam at 100°C did not result in any appreciable loss of phospholipase activity (95b). Phospholipase A is known to be remarkably heat stable; but the cod phospholipases in question seemed to involve both A and B, since both fatty acids were removed from the phospholipid molecules. These cod fillets were completely cooked in the culinary sense. Prolonging the heat treatment for 90 minutes resulted in complete destruction of all phospholipase activity. These results have obvious significance for such products as frozen pre-cooked fish.

The lipase of cod liver seems to be destroyed in the normal steaming process, which typically involves only a few minutes at the boiling point followed by perhaps 15 minutes settling while nearly at 100°C. There is some evidence (100, p. 82) that undercooked portions of the liver still contain an active lipase; but the possibility of incomplete microbial destruction in these portions cannot be excluded.

6. The effect of freezing

We now turn to consider the effects of the freezing process as such, independently of any effects of low temperatures during subsequent storage. Freezing involves damage to cell structures, concentration of solutes in the residual liquid water, and possible re-orientation of enzymes and their substrates.

It has been found that breakdown of phospholipids in the flesh of cod stored in the frozen state is far more rapid than would be expected at the temperatures in question, compared with the rates found at higher temperatures. This aspect is discussed in the next section. In other words, a break occurs in the relation between temperature and reaction rate. The precise temperature at which it occurs is still being sought in studies by Olley and Watson (102a); but an indication of the region in question is seen in Table XV. It will be seen that hydrolysis is considerably slower at — 2·4°C than at — 10°C, and that it reaches its maximum rate at some temperature intermediate between these values. Since it may be a significant factor, the percentages of the total tissue water which are frozen at the various temperatures are also shown in Table XV.

At temperatures a little above — 2·4°C a lag period is observed before rapid hydrolysis commences. This has been reported in studies with cod at 0°C (whether sterile or not) (95) and with herring stored in ice (96). The latter finding has been confirmed in current work by Olley and Watson (102a), who have also observed a lag of at least 5 days (the limit of that particular experiment) in cod stored at — 1·4°C. At this temperature some 35 per cent of the water in the tissue is frozen (103). The lag period at 0°C has been found to extend for about 10 days.

The existence of this initial lag at 0°C and — 1·4°C makes it difficult to compare reaction rates at these temperatures with those at lower temperatures, where no initial lag is observed. No lag was observed in samples stored at + 20°C (95b), but it is uncertain what final level of hydrolysis would be achieved at this temperature. The initial level of free fatty acids was appreciably higher in the frozen than in the unfrozen fish (see below), so that an accumulation of 20 per cent free fatty acids in the unfrozen material would represent an amount of hydrolysis equivalent to an accumulation of 25 per cent free fatty acids in the frozen samples. At + 20°C this level of hydrolysis is reached in about 4 days. Compared with 10 days at — 7°C this obviously suggests a marked acceleration due to the freezing process.

The abolition of an initial lag in fish stored at temperatures below about — 2°C suggests that freezing may, perhaps, be activating the system by liberating the

TABLE XV

Rate of hydrolysis of phospholipids in cod flesh stored at various te

Storage temperature	*k* (102)	*Half life of* (102) *phospholipids*	Q_5	dT	*Percentage of* (103) *water frozen*
−2·4°C . .	0·151 weeks^{-1}	4·6 weeks			60
			−51	−0·9	
− 4°C . .	0·531 0·342 ,,	1·3 2·0			73
			−1·9	−5·3	
− 7°C . .	0·506	1·4			81
			1·9	5·5	
− 10°C . .	0·346	2·0 ,,			84
			4·8	2·2	
− 14°C . .	0·0986	7·0 ,,			87
			3·6	2·7	
− 22°C . .	0·0129	53·8 ,,			89
			3·3	2·9	
− 29°C . .	0·00243 ,,	284·0 ,,			90

[1] The phospholipid concentration during frozen storage falls along an exponential curve, with a corresponding inverted curve for the accumulation of free fatty acids (FFA). The reaction always virtually ceases at about the same stage, namely when the lipids contain some 20–25 per cent of the original phospholipids and about 50 per cent of FFA. The reaction rate constants (k) and "half life" times were obtained from statistically-drawn curves for accumulation of FFA assuming a final level of 50 per cent. At − 7°C and below all samples were air-blast frozen at − 29°C and then stored at the temperatures stated. At − 2·4°C the samples were frozen by immersion of polyethylene-wrapped thin slices in alcohol-water at − 2·4°C. At − 4°C some samples were frozen by each method. The upper values for k and for half life at − 4°C are for immersion-frozen material, the lower values for air-blast frozen material.

enzymes from some sub-cellular structure damaged by the freezing process. The sort of structure envisaged would be something like the lysosomes of De Duve (104). This hypothesis has been tested by Olley and Watson (102a) by freezing cod, thawing it overnight in air at 4°C and then storing it in ice. Despite a certain amount of scatter in the results, probably attributable to biological variation, certain findings are quite definite. Rapid freezing of cod fillets in an air-blast freezer running at − 29°C, as used in the earlier published experiments (95b), did not abolish the lag, nor alter its duration. Moreover, the initial level of free fatty acids was not significantly altered. In the earlier work referred to (95b), whole fish were frozen in this freezer, at a considerably slower overall rate. Fillets frozen still more rapidly, in solid carbon dioxide, or fillets frozen very slowly by wrapping loosely in polyethylene and placing in still air at − 14°C, showed entirely different behaviour: the initial level of free fatty acids after thawing had risen from about 2 per cent to about 7 per cent, the lag period was completely abolished, but the whole course of hydrolysis was different. Instead of the typical exponential form, it followed virtually a straight line, with a slope considerably less than that of the steep part of the hydrolysis curve in ordinary iced fish. Love (105) has shown that structural damage by freezing may be least at intermediate rates of freezing.

Further evidence of the complexity of the influence of freezing on the hydrolysis of lipids in fish flesh is afforded by experiments (102a) in which fish were stored at − 7°C for one week, and then some of them thawed and kept in ice, the rest being left at − 7°C. There was, of course, no initial lag at − 7°C; and after one week over 20 per cent of free fatty acids had accumulated. In the fish then thawed and put in ice, further hydrolysis followed a straight line course, at a rate well below that of the fish left at − 7°C, in which the course was, as usual, exponential in form.

Another example of the influence of the freezing process, as distinct from the storage temperature, is afforded by the data in Table XV on fish stored at − 4°C. In fish frozen to − 29°C in an air blast freezer and then brought back to − 4°C, subsequent hydrolysis was slower than in fish cooled only to − 4°C by immersion. Here two possible factors are involved: (*a*) freezing rate, (*b*) proportion of the total water which was frozen, at one stage or another.

It may be noted that in all these experiments there was no evidence that thawing, as opposed to freezing, had any promoting action on lipid hydrolysis. It should also be pointed out that freezing made no difference to the type of hydrolysis produced (e.g. to the ratio of fatty acids liberated to lipid phosphorus lost, or to the relative proportions of various phospholipids hydrolysed), nor to the final equilibrium levels of products.

No comparable information is available on the effect of freezing on lipid hydrolysis in fish viscera: but it has been shown (106) that with lamb liver there is an initial lag in unfrozen material, no lag in frozen material, and that a preliminary freezing and thawing can abolish the lag in material kept in the unfrozen state.

7. The effect of storage temperature

Some reference has already been made to the effect of storage temperature on the rate of hydrolysis of lipids in cod flesh. No comparable investigations have been made with other species: but Dyer and Fraser (98) have reported studies with cod stored at 0°C, − 12°C, − 18°C and − 23°C; with halibut at − 12°C, − 18°C and − 23°C; and with rosefish stored at − 12°C and − 23°C. While their results agree in general with those obtained by the Aberdeen workers (95b) (102a), particularly in respect of the magnitude of the retardation by lower temperatures during frozen storage, they differ in the size of certain values, e.g. initial level of free fatty content. They also did not show an initial lag, nor a subsequent rapid hydrolysis, in cod stored in ice. Lovern *et al.* (95b) have pointed out that these differences were probably due to the admittedly incomplete and selective extraction techniques used in much of Dyer and Fraser's work, and to the method of determining free fatty acids. This section of the present paper will be based on the work with cod at Aberdeen.

In Table XV are given the rate constants (k) for production of free fatty acids (calculated for a first-order reaction, which best fits the experimental curves) and the "half life times" of the phospholipids in frozen cod flesh stored at various temperatures from − 2·4°C to − 29°C. Also given in Table XV are the percentages of the total tissue water frozen at the respective storage temperatures, the temperature coefficients (Q) over various temperature ranges, and the temperature increments (dT) required to double the reaction rate, over the same ranges. In view of the magnitude of Q, and its marked variation with temperature, it has seemed preferable to express the results for increments of 5°C (Q_5) rather than as the more usual Q_{10} values. In calculating Q_5 and dT for the interval − 4°C to − 7°C, the value of k determined on the air-blast frozen material subsequently stored at − 4°C was used. On the other hand, in calculating Q_5 and dT for the interval − 2·4°C to − 4°C, the value of k on the immersion-frozen material at − 4°C was used. Thus the effects of different freezing procedures have been eliminated as far as possible. The reason for adopting an immersion technique at − 2·4°C was to eliminate the very long delay in equilibrating a tissue frozen to − 29°C with still air at − 2·4°C in a cold store. Equilibration is quite rapid when it involves little change in the proportion of water frozen, e.g. up to − 7°C.

It will be noted that at temperatures a little below the freezing point the temperature coefficient is not only enormous but at the same time negative. Indeed, it is probably changing so rapidly with temperature that the value calculated for a five degree interval is quite unrealistic. Nevertheless, it does correctly convey the idea of a very high negative coefficient. At some point between − 4°C and − 10°C the temperature coefficient changes from negative to positive. From − 10°C downwards it slowly decreases with temperature, but remains high at least down to − 29°C. Thus a Q_{10} value for this reaction at normal cold storage temperatures would be about 10, instead of the typical value of about 2 for many reactions in non-frozen systems. Similarly high temperature coefficients have been found for other reactions in frozen tissues (107). The advantages of using really low storage temperatures are emphasized by the fact that even below − 22°C the reaction rate is halved for every three degrees drop in temperature.

It has long been realized that changes of many kinds take place very rapidly in fish at temperatures a little below the freezing point. Fish will keep better unfrozen in ice than when partly frozen. But the data in Table XV demonstrate that lipid hydrolysis in cod is most rapid at temperatures of − 4°C to − 7°C. Furthermore, the initial lag observed at 0°C is not abolished at temperatures just below the freezing point, e.g. − 1·4°C. It seems desirable that other tissue reactions should be studied in this temperature range, especially as there seems to be a parallel between the effect of temperature on rate of lipid hydrolysis and on rate of protein denaturation in frozen cod flesh (see section 12).

As indicated above (section 6), it is difficult to assess, from available data, the effect of storage temperature on lipid hydrolysis rates in unfrozen cod flesh. It is perhaps unrealistic to measure reaction rates at 0°C on the curves subsequent to the lag period, since it has been found (102a, b) that the tissue pH rises rather abruptly from values just below 7·0 to values slightly above 7·0 at the end of the lag period. The effect of pH on lipid hydrolysis rates in fish flesh has not yet been studied. Ignoring this factor, comparison of rates at 0°C and 20°C suggests that hydrolysis during the rapid stages proceeds about 3·3 times faster at 20°C than at 0°C (95b). This corresponds to a Q_{10} of about 1·8.

Fish viscera (e.g. livers) are often stored at low temperatures. In section 10 reference is made to the rate of lipid hydrolysis in frozen fish livers. However, it is difficult to compare these rates with those in unfrozen livers, because of uncertainty about bacterial effects in the unfrozen material (see section 4.2). It should also be noted that the extraction techniques used in preparing fish liver oils are seldom exhaustive, and may well be selective for such components as free fatty acids. Variability in the fresh material may be so great that it prevents really quantitative comparison from one series of experiments to another. However, in one carefully-controlled series with cod livers, ranging from samples steamed within an hour or so of removal from fish only a few hours dead to similar livers stored for periods of 5, 24, 48, 72 and 96 hours, Drummond and Hilditch (100, p. 81) found free fatty acid contents in the rendered oil of 0·07, 0·10, 0·18, 0·30, 1·05 and 1·50 per cent respectively. Storage was at ambient winter temperatures in the north of Scotland: say 0° to 5°C. These values may be compared with those found by Lovern (108a) for cod livers stored at − 12°C, which showed great variability from sample to sample, and from which the oils were recovered by solvent extraction rather than steaming. It required somewhere between 4 and 12 days at − 12°C to produce about 1·5 per cent of FFA in the oil, compared to 4 days at 0–5°C. After 4 days storage of cod livers at − 12°C, the extracted oil contained about 0·10–0·13 per cent FFA, a level reached in less than 24 hours at 0–5°C.

8. The effect of dehydration

Although freezing may be regarded as a form of dehydration, considerable proportions of liquid water remain even at temperatures of − 29°C (see Table XV). Fish meal normally contains about the same moisture content (10 per cent) as cod flesh frozen to − 29°C. It is well known that for dehydrated foods of many kinds far greater storage stability is achieved when the moisture content is reduced to very low levels. This is true of lipid hydrolysis. Thus Lea (109) reported the progressive and drastic retardation of hydrolysis in the fat of dehydrated, raw, minced beef, as the moisture content was reduced from 7·5 per cent to 1·5 per cent.

The dehydration to be considered here is not that involved in freezing, where it would in any case be difficult to disentangle its effects from those of the freezing process and of low temperatures. It is the dehydration achieved by low temperature drying of raw fish tissues, the products of which are usually subsequently stored without refrigeration. High temperature drying, or cooking of the product before drying, as in the manufacture of fish meal, may result in partial or complete inactivation of lipolytic enzymes (see section 5).

Very few data seem to be available on lipid hydrolysis in dehydrated raw fish. Unpublished results obtained at the Torry Research Station, Aberdeen, on dehydrated cod fillets prepared at the Experimental Factory of the Ministry of Agriculture, Fisheries and Food, Aberdeen, are given in Table XVI. These products were stored in sealed cans under nitrogen.

It can be seen that in sample 1, stored at − 5°C, there was very limited hydrolysis in two years. Free fatty acids may amount to 7–8 per cent in some samples of freshly-frozen cod (see section 6), and no data are available in this respect on freshly-prepared, freeze-dried cod. The phosphorus content of the lipids is a little below the value for fresh cod (about 3·0 per cent). The acidic phospholipids show a small but significant increase from the level of about 8 per cent (expressed as in Table XVI) for fresh cod (95b).

At 18°C there was again extremely limited, if any, production of free fatty acids in three years. There was, however, a somewhat greater loss of phosphorus than in the previous case, and a considerable increase in acidic phospholipids.

At 37°C there was appreciable production of free fatty acids, reaching 12–16 per cent in two years and 20–24 per cent in four years. Phosphorus fell to 2·0–2·4 per cent in two years and to 1·9 per cent in four years. Acidic phopholipids rose to 22–28 per cent in two years, but did not increase any further in the following two years.

In iced cod and in frozen cod, the only hydrolytic changes observed have involved more-or-less simultaneous liberation of both fatty acids from such lipids as phosphatidyl choline and phosphatidyl ethanolamine (see section 11). There has been no evidence of loss of lipid bases to give acidic phospholipids, nor of loss of phosphorylated bases to give diglycerides. In other words no evidence of the activity of phospholipases C and D.

The actual content of acidic phospholipids in stored dehydrated cod cannot be calculated, but it may well reach 50 per cent of the total phospholipids. It is, however, uncertain whether this hydrolysis is the result of phospholipase C activity. Although no detectable

TABLE XVI

Lipid hydrolysis in dehydrated raw cod fillets

Sample[1]	*Moisture content* (%)	*Storage conditions*		*Lipid content* (%)	*FFA* (% *in lipids*)	*Phosphorus* (% *in lipids*)	*Acidic*[2] *phospholipids*
1	3·3	− 5°C	2 years	3·6	8·3	2·7	12·5
2	3·7	18°C	3 years	4·4	7·2	2·5	21·7
3	2·9	37°C	2 years	3·1	16·3	2·0	22·9
4	3·5	„	„	3·7	12·7	2·4	21·6
5	3·5	„	„	3·8	11·7	2·3	25·6
6	3·5	„	„	4·3	12·6	2·2	27·8
7	3·3	„	4 years	3·9	20·3	1·9	24·2
8	3·3	„	„	3·2	23·9	1·9	23·6

[1] Samples 1–7 were prepared by "accelerated freeze drying", sample 8 by "vacuum contact drying" (110).

[2] Acidic phospholipids represent lipids (other than free fatty acids) titratable to phenolphthalein. Their mean equivalent weight is unknown and the values recorded above are calculated as if they were free fatty acids of mean equivalent 300 (95b).

non-enzymic hydrolysis of phospholipids occurs in cooked cod flesh at 0°C or at − 14°C over a period of 7 weeks (95b), the position may be different in dehydrated cod, at higher temperatures and for very long periods. Only comparison with control samples made from dehydrated cooked cod could settle the matter.

The same difficulty arises with the lipid phosphorus contents. The values fall below those to be expected from the accompanying increases in free fatty acids. In wet fish stored in ice, or in frozen fish, a phosphorus content of 2·5 per cent in the total lipids would be associated with about 20 per cent of free fatty acids, and a phosphorus content of 2 per cent with nearly 30 per cent of free fatty acids (95b). As can be seen from Table XVI, such phosphorus contents in the lipids of dehydrated cod are accompanied by smaller levels of free fatty acids. This may indicate activity by phospholipase D; but in the absence of data on dehydrated cooked fish any definite conclusion is unjustified.

TABLE XVII

Phosphorus and nitrogen contents of the total phospholipids of dehydrated cod flesh[1]

Sample	*Phosphorus*	*Nitrogen*	*N/P*
4	2·78	2·77	2·2
5	2·65	3·17	2·7
6	2·45	3·45	3·1
7	2·15	3·34	3·4
8	2·15	4·04	4·1

[1] Sample numbers as in Table XVI. Phosphorus and nitrogen as g./100 g. phospholipids. N/P is atomic ratio.

Chromatographic separation of the total phospholipids from the non-phospholipids reveals that the former suffer degradation of unknown nature during storage of dehydrated cod. Some data are given in Table XVII, which show that the phosphorus content falls even within this fraction (which could not result from hydrolysis alone), and that the nitrogen content increases. This nitrogen resists removal by the washing procedure of Folch *et al.* (8) and by chromatography on silicic acid. Since the acidity of the phospholipids increases, the extra nitrogen cannot be present as basic compounds. It may be present as amino acids or peptides, but no further information is available.

It may be noted that production of acidic phospholipids seems to cease after 2 years at 37°C, but that phosphorus content continues to fall.

Phospholipase A (or A-plus-B), liberating free fatty acids, shows little activity at − 5°C or 18°C; but free fatty acids are produced at 37°C, with practically no diminution in rate over a second 2-year period compared to the first 2 years. Again, tests on dehydrated cooked fish are desirable: but, in contrast to phospholipases C and D, phospholipase A (or A-plus-B) is known to occur in cod flesh.

The samples listed in Table XVI are of nearly uniform moisture content, and thus do not provide information on the influence of this factor.

9. The effect of salt

Very few data are available on the effect of salt on the course of lipid hydrolysis in fish tissues. Salt has sometimes been used as a preservative for fish livers. In tests with one species (the saithe, *Gadus virens*) it was shown (100, p. 82) that neither admixture with dry salt (and production of a saturated pickle), nor submersion in 10 per cent brine, gave any evidence of inhibition of lipase activity. Since these particular livers were absolutely fresh, bacterial effects might be regarded as negligible. After 60 hours in 10 per cent brine, and 6 days in saturated pickle (both at ambient Scottish summer temperatures), the livers were steamed to give oils with 4·1 per cent and 5·7 per cent free fatty acids respectively.

Canadian workers (111a, b) have studied the hydrolysis of lipids in cod flesh during both light salt curing (Gaspé cure) and heavy salt curing. In the former process (111a) lipid hydrolysis was progressive throughout, whereas with heavy salting it occurred mainly in the

TABLE XVIII

Production of free fatty acids in the lipids of cod flesh during the preparation of salt cod

Light salting (Gaspé cure)		*Heavy salting*	
Sample	*FFA (% in lipids)*	*Sample*	*FFA (% in lipids)*
Fresh fish . . .	13·1	—	—
After salting period (48 hrs.) .	21·0	Half way in salting period (10 days) . . .	45·5
After first drying period (36 hrs.)	34·7	End of salting period (18 days)	41·0
End of drying process[1] .	50·4	After first period of drying (36 hrs.)	49·2
		End of drying[1] process .	52·2

[1] Not specified by authors and depends on moisture content desired and drying conditions.

early stages. However, since the early stages of the heavy salting process are far longer than those of the light salting process, this difference may be more apparent than real. In both cases hydrolysis ceased when the lipids contained about 50 per cent of free fatty acids, i.e. at about the same level as in iced or frozen fish. The Canadian authors attributed the cessation of hydrolysis to enzyme inhibition by salt. In the present author's opinion, the similar course of hydrolysis under three widely-different sets of conditions (wet fish, frozen fish and salt fish) points to some common factor in progressive suppression of enzyme activity, such as inhibition by the reaction products. Some of the Canadian data are summarized in Table XVIII.

By comparison of the component fatty acids of the phospholipids of Gaspé-cured cod and of fresh cod (111b), it was calculated that the following proportions of various acids were liberated during the process: palmitic, 85 per cent; stearic 56 per cent; hexadecenoic, 96 per cent; C$_{18}$-unsaturated, 77 per cent; C$_{22}$-unsaturated, 81 per cent. Although the authors draw attention to the differences in some of these values, suggesting selective liberation, the possibility should not be overlooked of variation in the raw material, combined with analytical error.

Kleimenov *et al.* (111c) have followed the production of free fatty acids in the fat of Caspian herring during salt-curing and subsequent storage of the product in brine. After 9 days salting, when the salt content of the flesh was 13·8 per cent, the fish were regarded as "medium-salted". After 14 days salting, with 16·8 per cent salt in the flesh, they were "highly salted". Samples of each type of product were then stored in brine of four different strengths (*a*) the natural brine as produced, (*b*) brine isotonic with the fish tissues, (*c*) hypotonic brine, (*d*) hypertonic brine. For the medium-salted fish, brine strengths ranged from 17·0–20·5 per cent and for the highly salted fish from 21·7–24·7 per cent. The results of the four series, which were very similar, have been averaged in Table XIX. Storage was at 5–10°C. The method of lipid extraction, and total lipid content of the fish, are not given. It is thus impossible to say whether the free fatty acids produced could have been derived exclusively from phospholipids (as in iced herring; see section 10). Moreover, varying fat content could produce considerable variation from sample to sample in results expressed, as these are, on a total lipid basis. It will be noted that lipolysis tends to slow down and cease at about the same level in both series. The authors conclude that "different salt concentrations in the solution surrounding the fish, and in the fish meat, do not have any effect on the character of changes in the acid number of the fish fat."

TABLE XIX

Production of free fatty acids in Caspian herring during salt curing and subsequent storage[1]

Sample	*Curing*	
Fresh fish	5·7	
5 days in salt	8·2	
9 " " "	15·1	
14 " " "	16·2	
	Storage	
	(*a*)	(*b*)
As received	14·9	13·7
After 30 days	21·3	15·4
" 90 "	30·4	38·9
" 140 "	36·7	39·5

[1] Data of Kleimenov *et al.* (111c) Values are the "acid numbers" of the extracted fat (mg. KOH required to neutralize the FFA in 1 g. of fat). The free fatty acid content expressed as a percentage of the fat will be about half these values. Product (*a*) is "medium salted" after 9 days curing, product (*b*) "heavily salted" after 14 days curing.

Salt does not appear to inhibit lipolysis of the fat in fish roe during the making of caviar (111d).

10. The effect of biological differences

Although various species of fish have been mentioned in earlier sub-sections devoted to post-mortem lipid hydrolysis, no attempt was made to discuss the influence of species and other biological factors as such.

Different species of fish may exhibit quite different rates of lipid hydrolysis under any particular set of conditions. The actual lipids involved may also differ. Thus, in the flesh of the cod the content of triglycerides is so small, both absolutely and relative to phospholipids, that only hydrolysis of phospholipids is likely to be important. But in such a fish as the herring it might be expected that triglyceride breakdown would be more important than that of phospholipids. The danger of such facile assumption is emphasized below. Two aspects of lipid hydrolysis may be considered: (*a*) the type of lipids involved, and (*b*) the rate of the reaction under defined conditions.

Olley *et al.* (102b) have studied the course of lipid hydrolysis in the flesh of 15 species of fish, each stored at two temperatures, − 7° and − 14°C respectively. It was found previously with cod (95b) that production of free fatty acids, plotted against lipid phosphorus, shows a straight line relationship. The slope of this line is the same as that for theoretical breakdown of lecithin or similar phospholipid to 2 molecules of free fatty acid (per molecule of phospholipid) and water-soluble phosphorus derivatives.

Production of fatty acids, relative to lipid phosphorus lost, faster than the above relationship permits, would imply either simultaneous hydrolysis of some non-phospholipid or the partial splitting of phospholipids to give lysophosphatides (or of both types of hydrolysis occurring side by side). Low rates of fatty acid production, relative to lipid phosphorus lost, would imply some hydrolysis by phospholipase D to give a diglyceride plus a water-soluble phosphorus derivative.

Some of Olley *et al.*'s data (102b) are summarized in Table XX. The total lipid contents give an indication of the amounts of non-phosphorus-containing lipids

TABLE XX

Type of hydrolysis in the flesh lipids of various species of fish during storage[1]

Species	*No. of samples*	*Total lipids*	*FFA from phospholipids*
Cod	105	0·67	98·9 (6·9)
Saithe	10	0·83	86·5 (16·0)
Ling	9	0·64	102·5 (22·3)
Hake	4	2·26	91·9 (36·6)
Halibut	22	0·76	77·5 (10·0)
Lemon Sole	22	0·85	76·4 (11·2)
Dab	7	2·15	47·0 (15·2)
Witch	6	0·84	88·4 (29·1)
Megrim	4	2·03	122·5 (39·4)
Angler Fish	7	0·61	61·8 (35·3)
John Dory	7	1·27	56·7 (51·8)
Gurnard	6	3·42	45·6 (19·1)
Herring	18	4·4	118·7 (9·7)
Skate	12	0·77	– 20·8 (48·1)
Nursehound	7	0·67	– 25·6 (82·4)
Dogfish	23	9·6	3·3 (9·6)

[1] Data of Olley *et al.* (102b). Species as in Table IV. Total lipids are mean values as g./100 g. fresh tissue. FFA (free fatty acids) from phospholipids as a percentage of the total FFA production (standard error in parentheses). Herring stored at 0°C, other species frozen at – 7° and – 14°C.

which may be present. Values in excess of about 1 per cent probably signify the presence of some depot fat (see section 1.2). Values of about 0·6–0·8 per cent indicate that the lipids are mainly composed of phospholipids. The percentages of the free fatty acids which are derived from phospholipid hydrolysis are calculated from the slopes of the relevant FFA/lipid-P regression lines, compared with the theoretical line for simultaneous loss of both fatty acids from lecithin. Results of storage at both – 7°C and – 14°C were pooled in drawing such regression lines, since rate of hydrolysis is not significant in this aspect of the phenomena.

In some cases the number of samples available was too few, and the scatter of the results too wide, for small deviations from 100 in column 4 to be significant. In general it can be said that in all those Teleostean species examined (i.e. all except the last three in Table XX) in which phospholipids account for virtually the total lipids, there is no evidence of accumulation of lysophosphatides (values significantly below 100 in column 4). The low value for the angler fish is associated with a wide scatter and its significance is doubtful.

When depot fat is present, it may or may not be appreciably hydrolysed simultaneously with the phospholipids. There is good evidence for it in the dab and the gurnard; less satisfactory evidence (bad scatter) for the John Dory; and no evidence of triglyceride hydrolysis in the hake, megrim and herring. Admittedly these herring were "spent" fish near the end of a long period of mobilization of depot fat, and were stored unfrozen at 0°. Admittedly only four samples of cold-stored megrims and four of hake were available. In two cases, however, the values actually determined exceeded 100 per cent. Activity of a phospholipase D, which could produce this effect on the slope of the regression line, has never been detected by reliable means (e.g. chromatographic evidence of the production of diglycerides) in fish flesh. It seems preferable to conclude, provisionally at least, that the slight excess over 100 per cent in these cases is due to experimental inadequacy.

The most startling data in Table XX are those for the three Elasmobranch species, the last three in the list. In two of them the lipids consist almost entirely of phospholipids. Virtually no breakdown of these occurs during storage. The result is a wide scatter and no true plot of a regression line. The correct answer in column 4 is probably zero. In the third Elasmobranch, where there is plenty of depot fat (a mixture of triglycerides and alkoxydiglycerides), free fatty acid is produced from this, but again virtually none from the phospholipids of the flesh.

Thus, all Teleosts yet examined contained a phospholipase A (or A-plus-B) in the flesh, whereas of the three Elasmobranchs examined none showed any evidence of its existence. Some species, including representatives of both Teleosts and Elasmobranchs, contained a flesh lipase, others showed no evidence of its presence. Some further examples of species variation in enzyme content are given below for liver tissue.

Olley *et al.* (102b) further found that the rate of hydrolysis (as measured by the content of free fatty acids in the tissue) was comparable for most of the species listed in Table XX. This was true at both – 7° and – 14°C. The exceptions were (1) a high (approximately double) rate of production of FFA in the dogfish (perhaps explicable by the high lipid content, with FFA values expressed on a tissue basis), and (2) appreciably slower hydrolysis rates in the angler fish and the John Dory, and extremely low rates in the skate and nursehound. The last finding can be attributed to the virtual absence of triglycerides and of an enzyme to hydrolyze the phospholipids.

Some rather fragmentary data (108a) on fish livers stored at about – 12°C indicate that there are appreciable differences in the lipase activity of different species. In these experiments, with very oil-rich tissues and results expressed on a total lipid basis, the influence of phospholipid hydrolysis can be ignored. In a skate (*Raia batis*), there was no evidence of any liver lipase activity over a period of 42 days. Hydrolysis was appreciable and comparable in the livers of cod and ling. It appeared to be considerably more rapid in the liver of the angler fish, and only part of the difference can be attributed to the somewhat lower oil content of angler fish livers. *In vitro* tests with liver extracts (108b) confirmed the higher lipase content of angler fish liver.

In the one species studied (cod), evidence was found for more active lipolysis in the livers of young (immature) fish than of older fish (108b).

11. The course of phospholipid hydrolysis

In previous sections, while the activity of lipase has been distinguished from that of phospholipase, no attention has been given to the relative rates of hydrolysis of the various types of phospholipid present in fish flesh (see section 1.2). Bligh (15) has demonstrated that, in frozen cod muscle, phosphatidyl choline and phosphatidyl ethanolamine are hydrolyzed at comparable rates, whereas phosphatidyl serine and phosphatidyl inositol were apparently not hydrolyzed at all in up to 37 weeks at about — 12°C. It has likewise been shown by Lovern *et al.* (14) that, in iced cod, phosphatidyl choline and phosphatidyl ethanolamine are hydrolyzed at the same rate. Unfortunately, the data on iced cod are inadequate (mixed fractions and incomplete analyses of some of them) for calculation of the rates of hydrolysis of phosphatidyl serine and phosphatidyl inositol.

As indicated earlier (section 10) it has been found with cod, both frozen and unfrozen, that two molecules of fatty acid are liberated per atom of lipid phosphorus lost (95b). If hydrolysis proceeds by stages (e.g. lecithin →lysolecithin→glycerophosphoryl choline), the second stage must proceed as rapidly as the first, and be effective at very low levels of substrate, since lysophosphatides do not accumulate. The position in other species is under investigation, but the data discussed in section 10 suggest that such accumulation cannot be extensive. In no case has an accumulation of diglycerides or of phosphatidic acid been observed, i.e. there has been no evidence of the presence of phospholipases C and D.

12. The significance of lipid hydrolysis

In contrast to oxidative changes in fish lipids, hydrolysis by itself has no obvious nutritional significance. Accumulation of free fatty acids is undesirable in oils which are to be extracted and marketed as such, e.g. fish liver oils or oils recovered during fish reduction operations. But in fish tissues to be consumed as such, any effects of lipid hydrolysis on culinary quality are likely to be due to secondary changes, e.g. possibly increased susceptibility to oxidation and development of off-flavours. One such secondary effect has been emphasized by Canadian workers. Since the lipids, particularly the phospholipids, are intimately associated with protein, it is possible to envisage lipid hydrolysis affecting the stability of the protein towards denaturing influences, e.g. during freezing and cold storage. Dyer *et al.* (98, 112) have emphasized that in cod there is a remarkable similarity between the rates of lipid hydrolysis and of protein denaturation, as measured by loss of solubility in 5 per cent sodium chloride solution. Moreover, this similarity extends to the effect of temperature on rate of change. They have further suggested that the known greater stability of the protein in such species as rosefish and halibut, compared to cod, may be due to a higher lipid content, and hence a longer time required to reach a critical level of hydrolytic breakdown.

Olley *et al.* (102b) have confirmed the similarities for cod, but have shown that generalization about species differences is dangerous. For frozen cod they have plotted the regression line for rate of lipid hydrolysis against temperature of storage, and have shown that it is almost superimposable on the regression line for protein denaturation rate (loss of solubility in 5 per cent NaCl) against storage temperature. When, however, protein denaturation curves for other species (namely lemon sole, halibut and dogfish) were compared with the corresponding lipid hydrolysis rates, all correlation failed. Data on protein denaturation in these three species were available only for storage at —14°C, and it is not known whether for each of them the regression line of degradation rate against temperature would be the same for lipid hydrolysis and for protein denaturation. But it is certain that lipid content and hydrolysis rate cannot be correlated simply with protein denaturation regardless of species.

The four species studied varied greatly in total lipid content, and hence in results for free fatty acids or lipid phosphorus expressed on a total lipid basis. Moreover, there was appreciable scatter in the initial levels of phospholipid and total lipid in the various samples. Nevertheless, certain findings were so marked and consistent that it is reasonable to summarize them as in Table XXI.

The differences in protein denaturation rates are very great, and it will be seen that the relative order of the species in column 1 of Table XXI is not duplicated in any other column. The dogfish results are interesting. Phospholipid breakdown was virtually non-existent. There was a high rate of production of free fatty acids in the tissues, but great dilution of this by depot fat.

TABLE XXI

Protein denaturation and lipid hydrolysis in the flesh of fish stored at — 14°C [1]

Protein denaturation	*Accumulation of FFA*		*Loss of phospholipids*	
	In tissue	*In lipids*	*In tissue*	*In lipids*
Lemon sole . . .	Cod, Halibut, Sole	Dogfish	Dogfish	Dogfish
Halibut	—	Sole	Halibut	Halibut
Dogfish	—	Halibut	Sole	Sole
Cod	Dogfish	Cod	Cod	Cod

[1] Rate of reaction increases down each column.

Considering only the three Teleosts, the only lipid column in which the order of increasing rate of change agrees with that in column 1 is that for accumulation of free fatty acids as a percentage of the total lipids (column 3). Expressed on a tissue basis, the three species show identical rates of accumulation of free fatty acids, and the differences on a lipid basis are small. They in no way correspond to the great differences in protein stability.

The possible significance of lipid hydrolysis under other processing or storage conditions is obscure. In iced fish, at least in the species studied (cod, herring, lingcod), the initial lag period will probably cover most of the period of storage. The very fragmentary data on lipid hydrolysis in dehydrated cod (Table XVI) cannot be assessed as a factor in quality deterioration as revealed by the studies of Matheson and Penny (113). Likewise there is no evidence of the significance of lipid hydrolysis in salt fish.

CONCLUSION

Knowledge of the component lipids of fresh fish is far more extensive than knowledge of the effects of processing on these lipids. For fresh fish, more information is desirable on the non-depot lipids of vertebrates, and for all classes of lipids from invertebrates. Agents responsible for hydrolysis during processing and storage are often difficult to study in isolation, e.g. bacterial versus autolytic agents. The effects of freezing must be distinguished from those of low temperature storage. The possible significance of lipid hydrolysis on the quality of processed fish requires further study, and its understanding will probably involve some elucidation of the association of lipids with proteins in cell structure.

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It is to improve the primitive methods of handling and processing fish that much scientific work is being directed. But before the fish can be processed and used they must be caught and here is a view of the catch of 20,000 catfish in Ceylon where FAO has done, and is still doing, much to mechanize fishing craft and methods.

OXIDATION OF FISH LIPIDS

by

H. S. OLCOTT

The highly unsaturated lipids of fish are readily susceptible to attack by molecular oxygen. The reaction proceeds by a free radical mechanism, and is therefore characterized by an induction period followed by an accelerating rate of oxygen absorption with concurrent developments of peroxides, rancid odors, and polymerized products. The rate of initiation of free radical chains is increased by light, heat, irradiation, and heavy metals. Free radicals react with oxygen to yield peroxy radicals, which then abstract hydrogen from substrate yielding hydroperoxides and new free radicals. A single chain is thus continued, but new chains result from the breakdown of the hydroperoxides to give new free radicals. Ultimately a plethora of reaction products results.

The attack of fish lipids by oxygen can be hindered by added antioxidants, which act as free radical chain breakers or as peroxide-decomposers. Unusual synergistic effects are demonstrable with mixtures of antioxidants. No satisfactory theory is available to explain the variations observable with different antioxidants or mixtures, since the results depend to an unpredictable extent on the nature of the substrate, the temperature, and other variables. Examples will be given.

Nutritional damage from the ingestion of oxidized fish lipids is caused by the toxicity of the peroxides, either elicited as such or from further oxidative reactions *in vivo*. Polymers would be expected to be damaging, insofar as they are no longer nutritionally available. Other of the numerous end-products of oxidation may also have deleterious effects. In general the adverse effects of fish oils oxidized *in vitro* or *in vivo* reflect secondary damage, due to the formation of free radicals from the decomposition of peroxides. Thus the ability of free radicals or peroxides to destroy vitamins A and E is reflected by various deficiency symptoms. Loss of lysine in stored or heated fish meals is probably due to reaction of carbonyl compounds.

L'OXYDATION DES LIPIDES DE POISSON

Les lipides du poisson contiennent des acides gras hautement insaturés, qui les rendent susceptibles d'être facilement attaqués par l'oxygène. La réaction s'effectue par un mécanisme à radicaux libres, et elle est caractérisée de ce fait par une période d'induction suivie par une absorption à vitesse accélérée de l'oxygène avec un développement corrélatif de peroxydes, d'odeurs rances et de produits de polymérisation. La vitesse d'initiation des chaînes de radicaux libres est augmentée par la lumière, la chaleur, l'irradiation et les métaux lourds. Les radicaux libres réagissent avec l'oxygène pour fournir des radicaux peroxy, qui alors soustrayent l'hydrogène des hydroperoxydes du substrat et des nouveaux radicaux libres. Une chaîne simple est ainsi poursuivie; mais de nouvelles chaînes résultent de la rupture des hydroperoxydes pour donner de nouveaux radicaux libres. En fin de compte, il en résulte une pléthore de produits de réaction.

L'attaque des lipides du poisson par l'oxygène peut être retardée par l'addition d'antioxydants agissant par rupture des chaînes de radicaux libres ou par décomposition des peroxydes. Des effets synergétiques inhabituels peuvent être constatés avec des mélanges d'antioxydants. On ne dispose encore d'aucune théorie satisfaisante pour expliquer les variations qu'on peut observer avec les différents antioxydants ou mélanges d'antioxydants, car les résultats dépendent d'une façon imprévisible de la nature du substrat, de la température et d'autres variables. On fournit des exemples.

Les dangers alimentaires d'une ingestion de lipides oxydés de poisson sont provoqués par la toxicité des peroxydes, soit d'origine immédiate, soit issus de réactions d'oxydation ultérieure *in vivo*. On devrait s'attendre à ce que les polymères soient nocifs, s'ils étaient disponibles plus longtemps pour la nutrition. Certains autres des nombreux produits finaux de l'oxydation peuvent également présenter des effets délétères. En général, les effets nocifs des huiles de poisson oxydées *in vitro* ou *in vivo* traduisent des dégâts secondaires dus à la formation des radicaux libres par la décomposition des peroxydes. Ainsi la capacité des radicaux libres ou des peroxydes à détruire les vitamins A et E est mise en évidence par divers symptomes de déficience. La perte en lysine dans les farines de poisson entreposées ou cuites est probablement due à la réaction des composés carbonylés.

LA OXIDACION DE LOS LIPIDOS DEL PESCADO

Los lípidos de pescado contienen ácidos grasos altamente no saturados que los hacen susceptibles de ser atacados fácilmente por el oxígeno. La reacción se efectúa por un mecanismo de radicales libres y se caracteriza por un período de inducción seguido por una absorción a velocidad acelerada de oxígeno, con produción correlativa de peróxido, olores rancios y productos de la polimetización. La velocidad de iniciación de las cadenas de radicales libres la incrementa la luz, el calor, la irradiación y los metales pesados. Los radicales libres reaccionan con el oxígeno para producir radicales peroxi, los que extraen el hidrógeno de los hidroperóxidos del substrato y de nuevos radicales libres. De esta manera continúa una sola cadena, pero se producen nuevas cadenas del desdoblamiento de los hidroperóxidos para dar nuevos radicales libres. Finalmente, esto resulta en una plétora de productos de la reacción.

El ataque de los lípidos de pescado por el oxígeno puede retardarse por adición de antioxidantes que actúan por ruptura de las cadenas de radicales libres o por descomposición de los peróxidos. Los efectos sinergéticos no habituales se pueden demostrar con mezclas de antioxidantes. Todavía no existe una teoría satisfactoria para explicar las variaciones que se pueden observar con diferentes antioxidantes o mezclas de éstos, porque los resultados dependen hasta un grado imprevisible de la naturaleza del sustrato, la temperatura y otras variables. Se darán ejemplos.

Los peligros alimentarios de la ingestión de lípidos de pescado oxidados los causan la toxicidad de los peróxidos, bien de origen inmediato, o de reacciones de oxidación ulteriores *in vivo*. Podría esperarse que los polímeros fuesen nocivos en la medida en que han dejado de estar disponibles para la nutrición. Algunos otros de los numerosos productos finales de la oxidación también pueden tener efectos deletéreos. En general, los efectos nocivos de los aceites de pescado oxidados *in vitro* o *in vivo* reflejan daños secundarios debidos a la formación de radicales libres a partir de la descomposición de los peróxidos. Así, la capacidad de los radicales libres o peróxidos de destruir las vitaminas A y E se pone en evidencia por diversos síntomas de deficiencia. La pérdida de lisina en las harinas de pescado almacenadas o calentadas probablemente se debe a la reacción de los compuestos carbonilo.

THE lipids of fish are characterized by a high degree of unsaturation in the form of multiple double bonds in the fatty acids. These are susceptible to attack by molecular oxygen. Such oxidation is known to proceed by a free-radical mechanism. It is characterized by an induction period during which oxidation is slow, followed by an accelerating rate of oxygen absorption with concurrent development of hydroperoxides, rancid odors, and polymerized products. As shown in Fig. 1 a hydrocarbon free-radical adds oxygen to yield a peroxy-radical, which in turn abstracts hydrogen from an unoxidized substrate molecule yielding hydroperoxide, and another hydrocarbon free-radical. A single chain is thus continued. The acceleration of the reaction is due to the new chains which result from the breakdown of hydroperoxides to give new free-radicals.

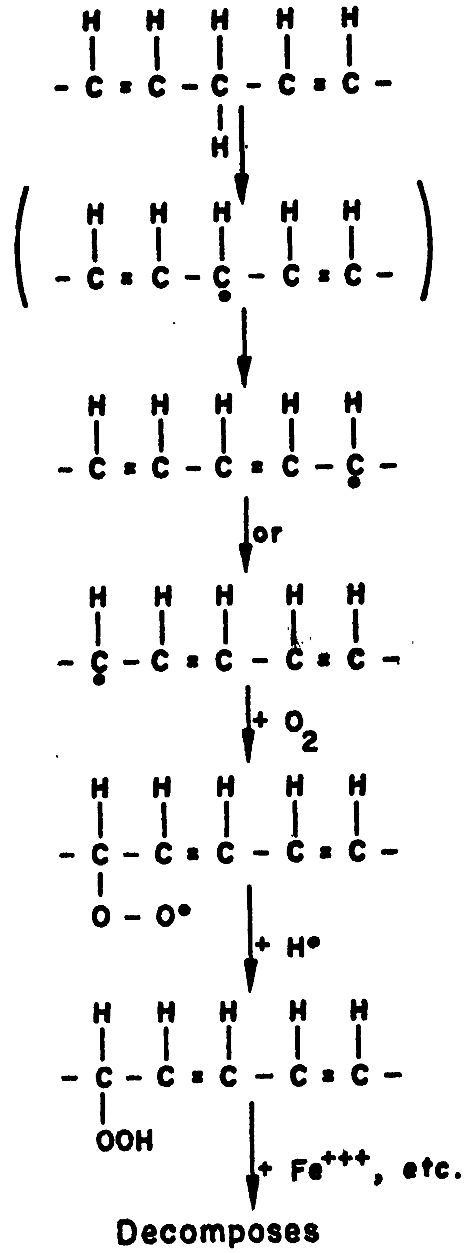

Fig. 1. Autoxidation of polyunsaturated fatty acids.

Some of the fatty acids of fish contain multiple ethylyenic bonds which appear to be solely of the methylene-interrupted variety: for example, 4, 7, 10, 13, 16, 19-docosahexaenoic acid. Hydrogens of the methylene groups are available for reaction with peroxy radicals, whereupon a shift of double bond to conjugated linkage and radical transfer occurs (Fig. 1). These reactions, the theory of which is that of Farmer (1), have been substantiated for methyl linolenate (2). Similar studies with the highly unsaturated lipids of fish will be extremely difficult because of the large number of potential isomers. Thus Frankel *et al.* (2) were able to separate the 4 hydroperoxides of octadecatrienoic acid from autoxidized methyl linolenate. The six double-bonded 22 carbon acid from menhaden oil mentioned above would be expected to yield 10 isomeric hydroperoxides, each containing three or four active methylene groups.

The next step in the autoxidation is a decomposition of hydroperoxide characterized by both scission and polymerization of the hydrocarbon chains, with further oxidation of susceptible fragments. The nature of these subsequent breakdown products has been most extensively studied for vegetable oils. This work has been reviewed recently by Evans (3) (Table I). No detailed studies have yet been made of fish oil breakdown products, but again they would be expected to be remarkably more complicated. Table II shows a comparison of the unsaturated fatty acids of menhaden oil with those of soy bean oil. The complexity of the breakdown products would be multiplied by the fact that the fish oils are composed of triglycerides, in which the various fatty acids exist in numerous combinations, as esters of glycerol. The quantitative nature of these combinations has yet to be worked out.

TABLE I

Products of decomposition of hydroperoxides of vegetable oils

Volatiles	*Non-volatile Polar Compounds*	*Polymers*
Aldehydes	Aldehydes	Dimers
Ketones	Ketones	Trimers
Hydrocarbons	Hydroxyl comp.	Higher polymers
Alcohols	Acids	
At least 200 different compounds		

(Adapted from Evans (3))

Antioxidants and pro-oxidants

However interesting may be the oxidation products of fish lipids, the principal aim of the technologist wishing to use fish as food should be to prevent them from occurring. For this purpose, understanding of the factors which promote and inhibit oxidation is necessary. The following generalizations may be made: oxidation may be inhibited or slowed (a) by replacement of air with inert gases or vacuum, (b) by the use of substances which can chelate or inactivate heavy metals, and (c) by antioxidants. Although numerous empirical studies on antioxidants have been made, investigators have often

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TABLE II

Comparison of composition of unsaturated fatty acids in menhaden and soy bean oil

No. of double bonds	*Percentage Composition* *Menhaden Oil* C_{16}	C_{18}	C_{20}	C_{22}	*Soy Bean Oil* C_{18}
1	9·8 (2)	14·5 (1)	—	—	23
2	2·0 (2)	2·7 (2)	1·2 (2)	—	49
3	1·3 (2)	1·3 (2)	2·0 (2)	—	8
4	2·0 (2)	3·2 (2)	0·6 (2)	—	
5	—		12·5 (1)	2·0 (1)	
6	—		—	8·9 (1)	

Adapted from Stoffel and Ahrens (4). Figure in parentheses indicates number of known isomers.

not used comparable techniques and contradictory results are reported.

It is beyond the scope of this paper to discuss the theories of antioxidant action. In his review of this field Ingold (5) has shown that antioxidant effects in gasoline, lubricating oils and pure hydrocarbons are parallel in many instances to those observed with edible fats and oils. Antioxidants for fats and oils may be arbitrarily divided into two groups: primary antioxidants, and synergists (6). The first group includes those which are effective in very small amounts; these in general are characterized by being hydroxyl or nitrogen derivates of aromatic compounds, and are free-radical acceptors. Those antioxidants which are permitted for use in the United States are shown in Table III. Alpha- and the other tocopherols are considered the most important natural antioxidants (7).

TABLE III

Partial list of Food additives permitted in the U.S.[1]

Antioxidants	*Synergists*
Tocopherols	Ascorbic acid
Butylated hydroxyanisole (BHA)	Erythorbic acid
Butylated hydroxytoluene (BHT)	Ascorbyl palmitate
Propyl gallate	Citric acid
Nordihydroguaretic acid (NDGA)	Isopropyl citrate
Gum guaiac	Stearoyl citrate
Thiodipropionic acid	Lecithin
Dilauryl thiodipropionate	Phosphoric acid

[1] Usually not more than 0·02 per cent.

Synergists are not effective inhibitors at the levels where primary antioxidants act, but do show remarkable additive effects. These results have been attributed to various effects: for example, the chelation of pro-oxidant heavy metals (8). Thus the efficacy of citric acid in hydrogenated soybean oils is said to be due to the chelation of trace amounts of residual catalyst (9). However, it is unlikely that all synergistic effects can be due to reaction with metals. Ingold (5) attributes certain synergistic effects to reaction with non-radical intermediates. Thus a free-radical acceptor (primary antioxidant) and peroxide decomposer (synergist) may together have more antioxidant activity than could have been predicted. In fact, it is probable that those antioxidants which eventually will prove to be most useful will be combinations of at least two and possibly more different oxidation inhibitors.

Unfortunately the information so far available is not sufficient to permit prediction. The effectiveness of various antioxidants and combinations of antioxidants and synergists differs with different substrates and conditions of testing. As an example, both ethoxyquin and a-tocopherol are efficient primary antioxidants; but in combination a-tocopherol interferes with or antagonizes ethoxyquin (10). As another example, it has been shown that the relative effectiveness of antioxidants in various substrates is influenced by the presence of free fatty acids, even in small amounts (11).

Many substances which normally occur in fish may act to promote or retard oxidation in fish products. The tocopherols have been mentioned. Amino acids have shown varying degrees of antioxidant, and also pro-oxidant, action (12, 13), depending upon concentration, pH, and other factors. Histidine has been found to be both an effective antioxidant and pro-oxidant. This amino acid occurs in relatively high concentration in the flesh of some marine fish (15). Ascorbic acid is also an antioxidant in fish products; one group has reported, however, that as a dip it protected color and flavor, but not against the development of rancidity (14). Phospholipids which occur in every tissue have long been known to act as antioxidant synergists (16). Recently we have shown that both purified lecithin and cephalin fractions are effective.

It has already been mentioned that heavy metals accelerate the oxidation of unsaturated fats. This is particularly marked with the naturally-occurring heme compounds (13, 17). It has been suggested that heme catalysis is the most important single factor in the oxidation of animal lipids *in situ* (13). The pro-oxidant activity is said to depend upon the ferric rather than the ferrous state (18).

On the other hand, Banks *et al.* (19) have recently shown that increasing amounts of cytochrome C tend to inhibit rather than accelerate the oxidation of methyl linoleate hydroperoxide. These contradictory results cannot be resolved in the present state of knowledge.

The effect of salt on oxidation of fish products has received attention in several laboratories. Most have observed accelerated oxidation in salted fish products. It has been suggested that this might be due to heavy metal impurities in the salt used; but the matter is still not satisfactorily explained.

The combined findings demonstrate clearly that the initiation and rate of oxidation of fish and fish products can be dependent upon the presence and interaction of numerous substances, both naturally occurring and added.

Oxidation of different fish products

Oxidation of frozen whole fish causes the development of rancidity, fading of carotenoid pigments (e.g. salmon), and formation of rust, a brown discoloration. Numerous studies have been made on methods of avoiding these changes. Low temperatures and glazing are useful. The ascorbic acid dips help to retain color, but do not inhibit the onset of rancidity, under one set of conditions (14). The brown color is thought to result from the reaction of carbonyl breakdown products of hydroperoxides with nitrogenous substances. However, one study implies that the brown color is not a result of carbonyl-amine reaction (20).

Some cooked fish is particularly susceptible to rapid oxidation. Zipser and Watts (21) find that polyphosphates and ascorbic acid make an effective antioxidant combination, but the mechanism is unknown.

The manifold changes that occur in the manufacture and storage of fish meal have received much attention (22, 23, 24). Oxidation and heating are a major problem for meals made from fatty fish such as herring, sardine, and menhaden. The reaction begins during drying and can lead to excessive heating, charring and even fire, unless precautions are taken. These include removal of heat from stacks, turning, prevention of oxidation by antioxidants or storage of meal in bags which do not allow free ingress of air. The oxidative reactions which occur during heating, or during subsequent long term warm storage, can lead to a loss of the lysine values of the meal due to reaction of carbonyl compounds with the epsilon amino groups of the fish proteins (23).

March *et al.* (24) found that herring meal stored at − 20°C oxidized faster than at 25°C as shown by decreases in the amount of lipid extractible with ether and in its iodine number. The changes were prevented by antioxidants. It is suspected that the greater stability of fish meal at higher temperature may be due to antioxygenic materials which are formed.

Nutritional aspects

The nutritional disadvantages of oxidized fish lipids may be divided into those which occur from the ingestion of lipid materials, after oxidation has already occurred, and those resulting from *in vivo* reactions of highly unsaturated fatty acids. It is not possible to separate these clearly, inasmuch as oxidation actually may occur during the time the food is being prepared, ingested, absorbed, transported, or deposited. Post-absorptive oxidation phenomena will be reported upon elsewhere in this compendium.

The toxicity of oxidized fish lipids is attributable to the toxicity of the hydroperoxides (25, 26), which cause death when ingested or injected, either as concentrates or as pure compounds. Although the exact mechanism of toxicity is not known, evidence indicates that free-radicals arising from the decomposition of the hydroperoxides may be responsible. Specifically the intestinal wall may be the main site of injury when peroxidized fats are fed (26).

The toxicity of overheated vegetable and animal fats is due to polymers not precipitable by urea (27, 28). Similar polymers occur in heated fish lipids (29), and may occur in fish meals which have undergone "curing." There seems to be no good evidence for toxic effects of this nature in fish meals. In fact, the universal favor found with fish meals in stock feeding, despite their having been oxidized, speaks against such toxic products, except possibly in comparatively small amounts. The damage which can or might be done to *other* nutrients is probably of more importance than toxicity *per se.* Thus the oxidized lipids can be responsible for the co-oxidative destruction of carotenoids, vitamin A and vitamin E, probably by free-radical type reactions. Also the carbonyl compounds resulting from peroxide breakdown can react with amino groups in amino acids, proteins, phospholipids etc., with consequent loss of nutritive values.

In summary, the preservation of the nutritive values of fish products depends upon the prevention of oxidative attack on the lipids. This can be achieved as follows: (*a*) remove lipids, (*b*) prevent access to air or oxygen, (*c*) avoid contamination by pro-oxidants such as heavy metals, (*d*) add antioxidants or combinations of antioxidants and synergists, (*e*) avoid irradiation including light, (*f*) use low temperatures (for exception with fish meal, see text).

The references provided are not complete. Some of the more recent publications have been favoured.

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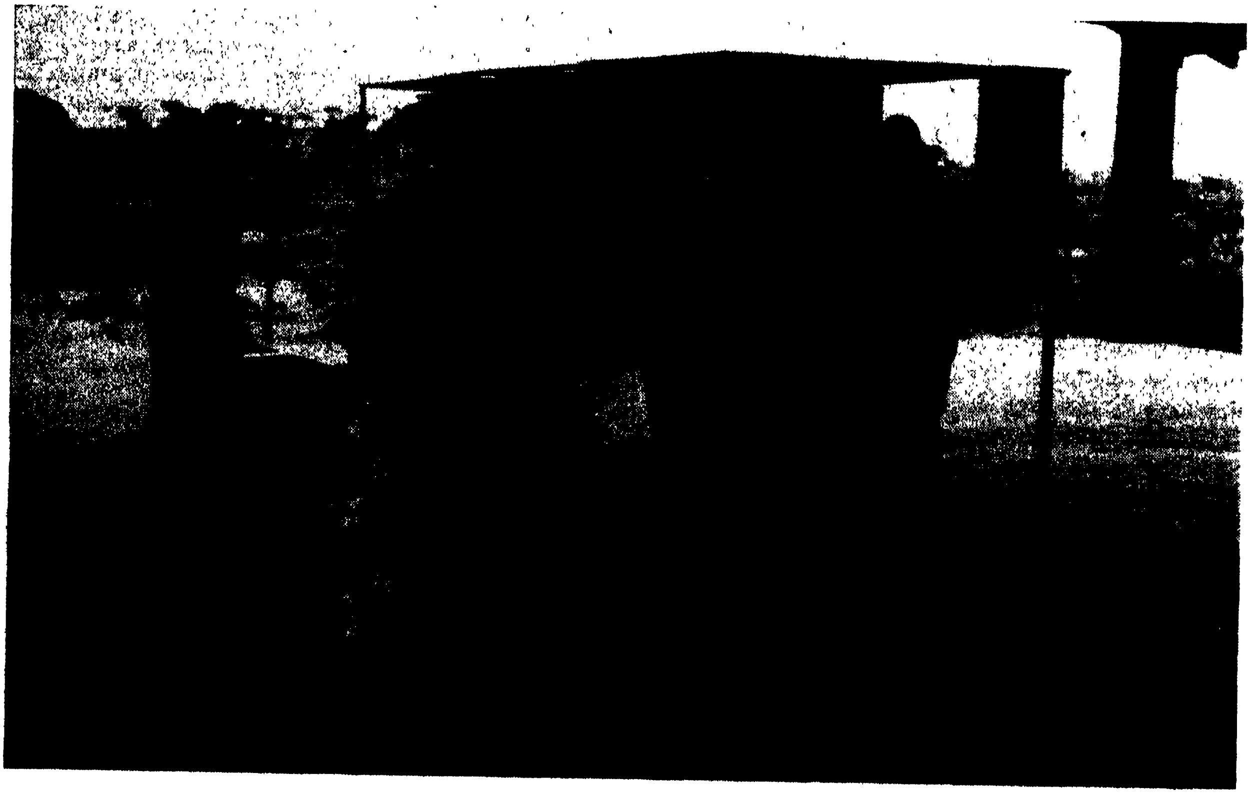

This is the pilot dryer devised by Dr. Kreuzer in his African journey for the purpose of improving regional methods of processing fish and preserving it for human consumption. It is described briefly in the companion picture on page 38, where are illustrated the traditional methods under which oxidation and other deterioration may develop.

SOME MODERN METHODS OF SEPARATION AND ANALYSIS APPLICABLE TO FISH OILS

by

RALPH T. HOLMAN

In recent years a number of physical methods for analysis of fats and lipids have been developed. Many of these are discussed, and examples of their application to fish lipids are given where possible. The methods include distillation, crystallization, adsorption chromatography, partition chromatography, paper chromatography, chromatography on glass paper, thin-layer chromatography, and gas phase chromatography. These, used singly or in combination, offer a much more definitive description and analysis of lipids than was possible only a few years ago.

QUELQUES METHODES MODERNES DE SEPARATION ET D'ANALYSE APPLICABLES AUX HUILES DE POISSON

Au cours des années récentes, un certain nombre de méthodes physiques pour l'analyse des graisses et lipides ont été mises au point. On examine plusieurs de ces méthodes, et l'on donne dans la mesure du possible des exemples de leur application aux lipides du poisson. Ces méthodes comprennent la distillation, la cristallisation, la chromatographie par partition, la chromatographie sur papier, la chromatographie sur papier en fibres de verre, la chromatographie en couche mince, et la chromatographie en phase gazeuse. Ces méthodes, utilisées seules ou en combinaison, permettent une description et une analyse des lipides plus précise qu'il ne l'était possible quelques simples années plus tôt.

METODOS MODERNOS DE SEPARACION Y ANALISIS APLICABLES A LOS ACEITES DE PESCADO

En los últimos años se han descubierto varios métodos físicos para el análisis de grasas y lípidos. Se discuten muchos de ellos, y siempre que es factible se dan ejemplos de su aplicación a los lípidos del pescado. Entre los métodos están: destilación, cristalización, cromatografía de absorción, cromatografía de partición, cromatografía sobre papel, cromatografía sobre papel de vidrio, cromatografía an capas delgadas y cromatografía de fases a través de gas. Empleados por separado o juntos ofrecen una descripción y análysis de lípidos mucho más definitiva de lo que era posible hace unos pocos años.

CHEMICAL evaluation of fish oils has changed its direction and objective with changes in the commercial use of these products, and the methods for evaluation of fish oils have followed suit. Formerly the chief utility of fish oils was their content of vitamins A and D, and the triglyceride vehicle which contained them received little attention. Although it was known that the oil was highly unsaturated, and subject to oxidation which produced vile flavors, the analysis of the component fatty acids was difficult and these components received little attention. Measurement of the extent of oxidation was of importance in predicting the shelf-life of the product, for oxidation not only decreased the vitamin A content but made the product unpalatable and unacceptable.

However, since the synthesis of vitamin A, the market for fish oils as a source of this vitamin has decreased, and outlets for other purposes have been sought. At the same time, several investigators discovered that highly unsaturated fatty acids in the diet have a pronounced effect in reducing the level of serum cholesterol, and are therefore believed to be beneficial in the prevention of atherosclerosis and accompanying heart disease. Also at the same time several new analytical methods, including gas chromatography, have proved to be very powerful and discriminating tools in analysis of the lipid component. These methods allow rapid analysis of the fatty acids, and reveal that most fats contain many more lipid fatty acids than were thought to be present. The combination of these circumstances has stimulated a strong interest in the characterization and analysis of fish oils. Many new constituents have been discovered, and their composition can be measured by a variety of methods.

The newer physical and chemical methods of analysis of lipids have been the subject of many reviews, and I do not intend to repeat these. In the time and space allotted, I cannot be either comprehensive or detailed. It is my purpose, therefore, to indicate a few of the newer approaches to the analysis of fats and oils, and to emphasize those with which I have had some experience. The reader is advised to consult standard treatises, monographs, and review articles for details and a wider selection of references (1–6). Whenever possible, examples of separation of lipids will be taken from the literature pertaining to fish oils. However, many of the new methods were first applied to other natural substances, and the best examples of their use involve other oils or lipids. But all the methods to be discussed apply equally well to fish oils.

Distillation

Traditionally, fractional distillation at low pressures has been a central method in the analysis of fats. For example, the school of Hilditch fractionated the methyl esters of mixed fatty acids by low pressure distillation as the separation step. Cuts or fractions of distillate were then characterized by iodine number, by thiocyanogen value, or by measurement of polyenoic acids by alkaline isomerization to give the final analysis of the oil. Most of our information on composition of fish oils was gained by these methods (7). This procedure is now only of historical interest. Fractional distillation is still used as a means of bulk separation for preparative purposes, or as a means of concentrating trace substances prior to analysis by another method. The latter purpose is illustrated by the work of Gellerman and Schlenk (8) who used fractional distillation to concentrate esters of fatty acids that have odd chain lengths to the point where they could be detected by chromatographic means.

Molecular distillation, or short path high vacuum distillation, is most frequently used in lipid chemistry in the separation of substances that differ widely in molecular weight and consequently have quite different vapor pressures. Thus, in commercial practice, fish oils have been subjected to molecular distillation to obtain vitamin A, and tocopherols have been similarly prepared from vegetable oils. The same equipment can be used to achieve partial fractionation of esters of mixed fatty acids. The degree of separation possible is illustrated in Fig. 1 showing the composition of serial fractions from a laboratory molecular distillation of methyl esters of cod liver oil (4).

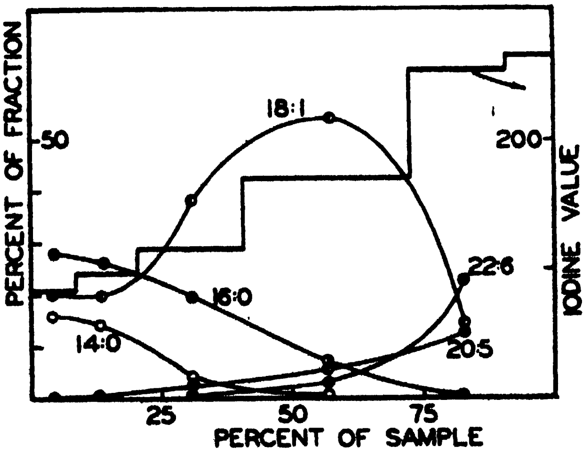

Fig. 1. Molecular distillation of methyl esters of cod liver oil. Chain length separation is indicated by the plots of one representative of each chain length group. Distillation and iodine value by courtesy of Robert Nørgaard, J. C. Martens Co., Bergen. From Fontell et al. (4).

Molecular distillation is also applicable to quantitative analysis. Privett *et al.* (9) have measured the content of mono-, di-, and tri-glycerides in samples of 0·5–2 g. at less than 10^{-8} mm. Hg. by observing the continual weight loss of the sample supported on a quartz fiber balance as the temperature is increased. One of their analyses is shown in Fig. 2.

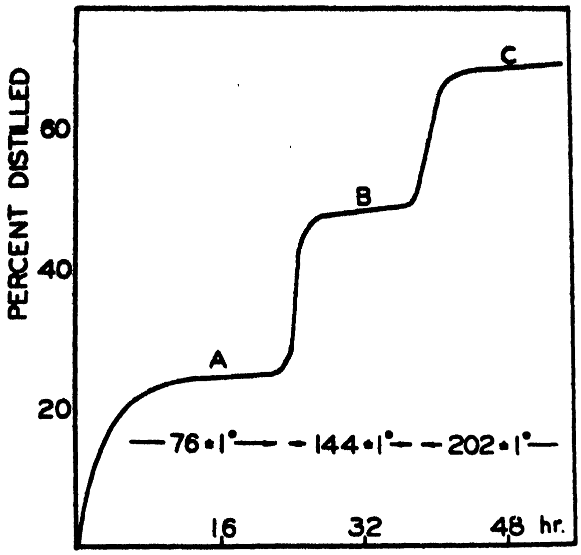

Fig. 2. Analytical molecular distillation of mono-, di-, and tri-glycerides. From Privett et al. (9).

Crystallization

The separation of fatty acids or esters by low temperature crystallization has been reviewed thoroughly by Brown and Kolb (10). This method, too, has its greatest use in bulk separations for purposes of preparation; it is useful in quantitation only as a preliminary step for concentration of constituents. In recent years, advances in development of this method have been few; but notable among these was the use by Schlenk and Ener (11) of liquid sulfur dioxide as a solvent for the fractionation. Acids, esters, and triglycerides can be separated into saturated and unsaturated components. For example, a 0·91 g. portion of menhaden oil methyl esters (iodine value 151·5) was crystallized from 40 ml. of SO_2 at —35° to —37°C. The solid fraction, 13·5 per cent of the total, had an iodine value of 1·2, whereas the liquid portion, 83 per cent, had an iodine value of 179. Similar treatment of crude menhaden oil (iodine value 177), separated 43·5 per cent as an insoluble fraction which was highly colored and had an iodine value of 112. The soluble portion, 52 per cent, had an iodine value of 210.

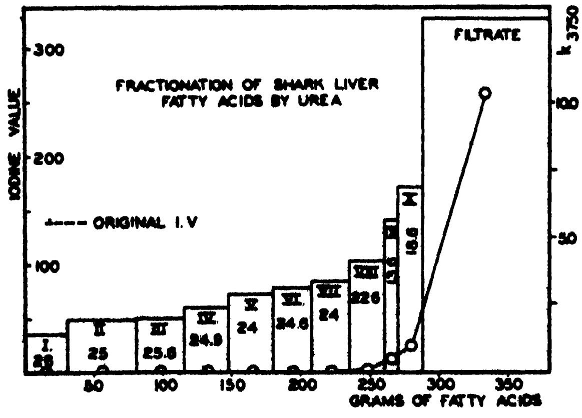

Fig. 3. Urea fractionation of shark liver fatty acids. From Abu-Nasr et al. (12).

Urea complex crystallization has in some respects replaced low temperature crystallization. Separations which may require subzero temperatures by the crystallization method can be achieved at temperatures above zero by urea complex crystallization. For example, successive fractions of shark liver oil fatty acids were separated by stepwise addition of urea (12). As the fractionation proceeded, the iodine value rose; but the filtrate from the last fractionation contained the major portion of the unsaturated acids (Fig. 3). When ethyl esters of cod liver oil fatty acids were subjected to the same procedure, the most highly unsaturated fatty acids formed complexes late in the scheme, indicating that esters of unsaturated acids form complexes more easily than do the free acids. Crystallization methods do not give all-or-none fractionation, but partial separations; they are useful in large-scale preparations and concentrating saturated or unsaturated acids or esters. For example, in studies of the metabolism of highly unsaturated acids, Klenk and Mohrhauer (13) used low temperature fractionation of mixed fatty acids prior to gas chromatographic analysis of their methyl esters.

Adsorption chromatography

In the separation of lipids, adsorption chromatography using charcoal has been mostly practiced as displacement chromatography (14). In this technique the sample on a column is developed by displacing it with a solution of a substance which is adsorbed more strongly than is any component of the sample. Thus, the components separate and travel as zones through the column, each displacing or pushing the next one lower in adsorbability. The chromatogram may be monitored by interferometry, paper chromatography, thin-layer chromatography, or by any other suitable means. In Fig. 4, the ethyl esters of the highly unsaturated acids of cod liver oil were separated by displacement chromatography, and the separation was monitored by paper chromatography and interferometry. These components were identified by alkaline isomerization, and one of them was isolated in 100 mg. quantities (5). Similar separations have been performed in the glyceryl ether series (5, 15).

The most commonly used form of adsorption chromatography in the lipid field is elution chromatography on silicic acid. This is now a routine method for separation of lipid classes, whatever their origin (16, 17). The separation of representatives of several lipid classes is shown in Fig. 5. By the appropriate choice of solvents, adsorption chromatography is also applicable to the separation of members of a class. Herb *et al.* (18) have used this technique for the isolation of several highly

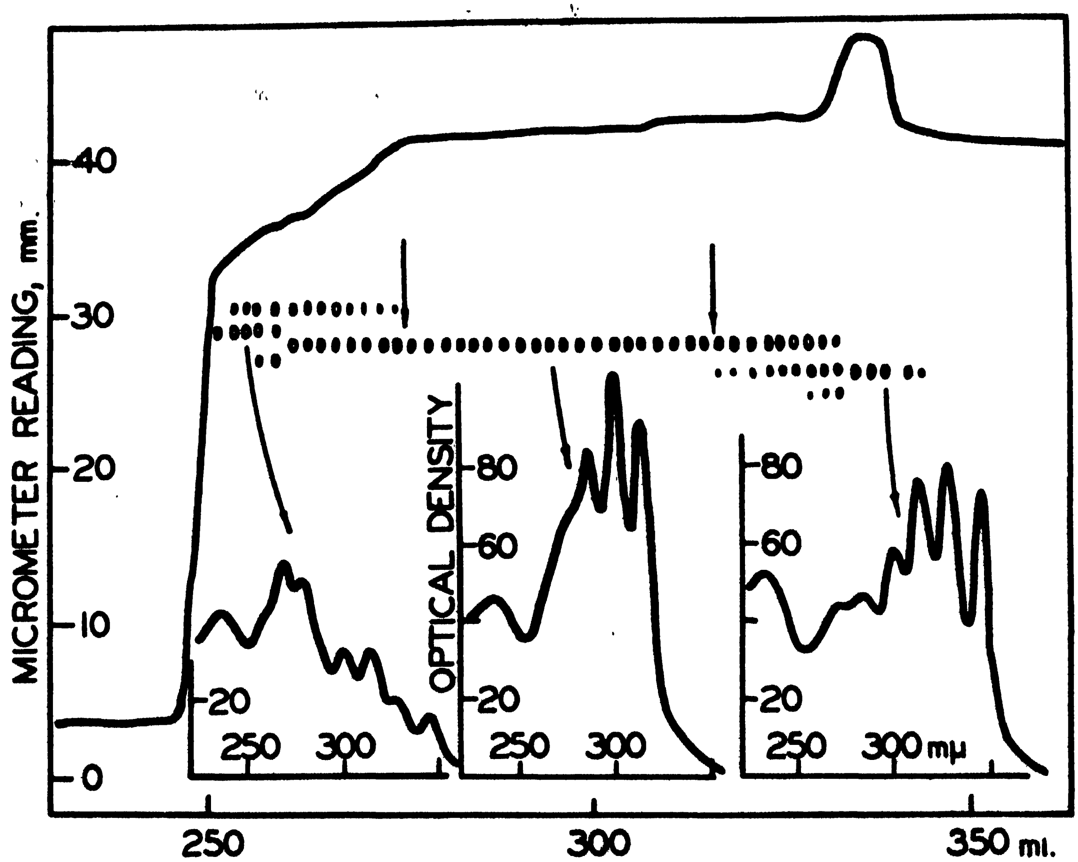

***Fig. 4.** Displacement chromatography of ethyl esters of highly unsaturated acids from cod liver oil. Upper curve represents refractive index of effluent obtained by interferometry. The series of spots indicate complexity of each fraction determined by paper chromatography. Inserts indicate ultraviolet spectra after alkaline isomerization, demonstrating the first fraction to be largely triene, the second tetraene, and the third pentaene. From Holman (5).*

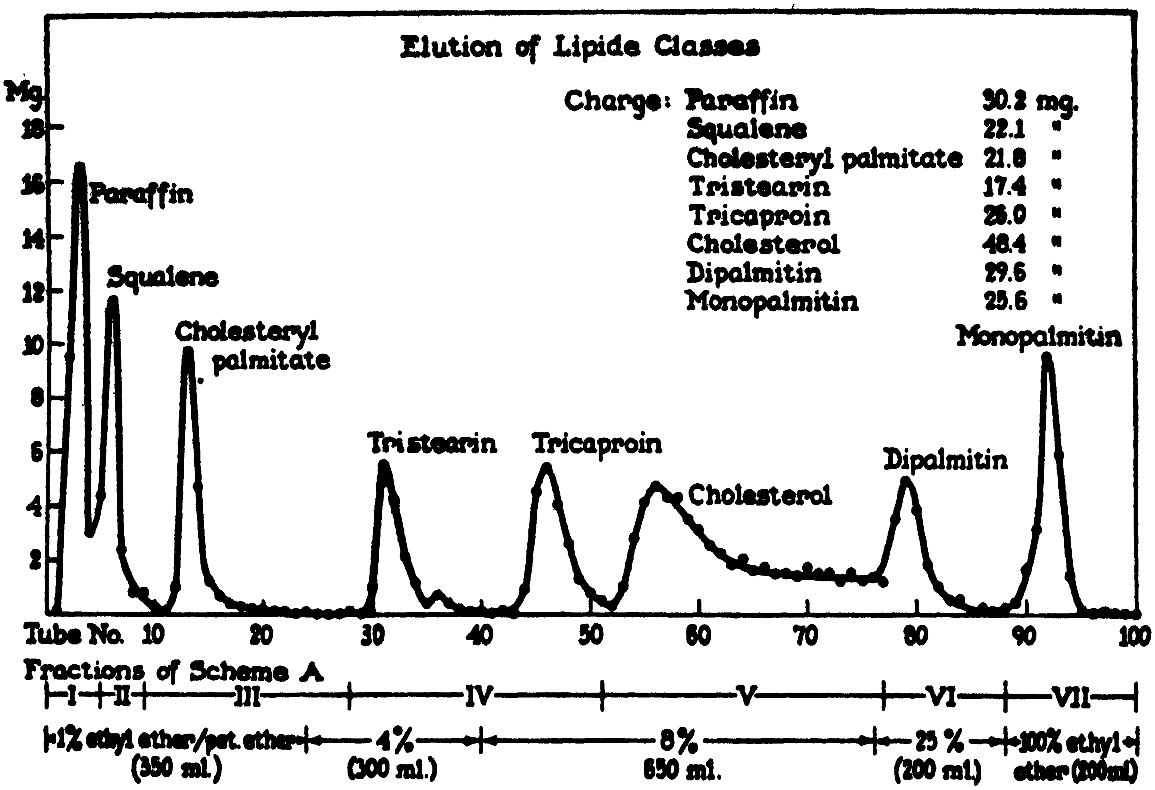

Fig. 5. Adsorption chromatography of several lipids of different classes on a column of silicic acid. From Hirsch and Ahrens (17).

unsaturated acids for use as standards in the alkaline isomerization analysis.

Partition chromatography

Reversed phase partition chromatography has been particularly successful in the separation of closely related lipid substances. It is currently being used in several forms for the isolation or measurement of fatty acids as their esters. Boldingh (19) used rubber columns for the analysis of herring oil, which was accomplished in two stages. The saturated acids remaining after oxidation of the unsaturated acids were separated and measured. The original mixture subjected to hydrogenation was analysed by the same means. The difference between the two analyses represents the unsaturated acids of each chain length (Fig. 6). Hirsch has applied rubber columns in the analysis of fatty acid methyl esters, using a recording refractometer to monitor the system. In this way he has been able to separate single methyl esters differing by degree of unsaturation (20).

Partition chromatography using acetonitrile-methanol-heptane on non-wetting celite is very effective in separating fatty acid esters which differ only by degree of unsaturation. For example, Privett and Nickell (21) have separated unsaturated fatty acid methyl esters from samples as large as 10 g., and have isolated several C_{18} esters. An example is given in Fig. 7. They have separated positional and geometric isomers of some

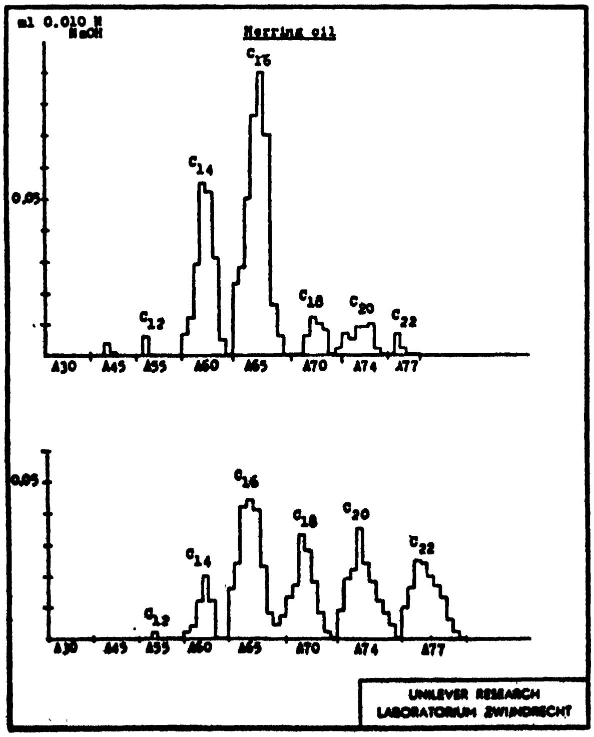

Fig. 6. Analysis of herring oil using partition chromatography on a rubber column. From Boldingh (19).

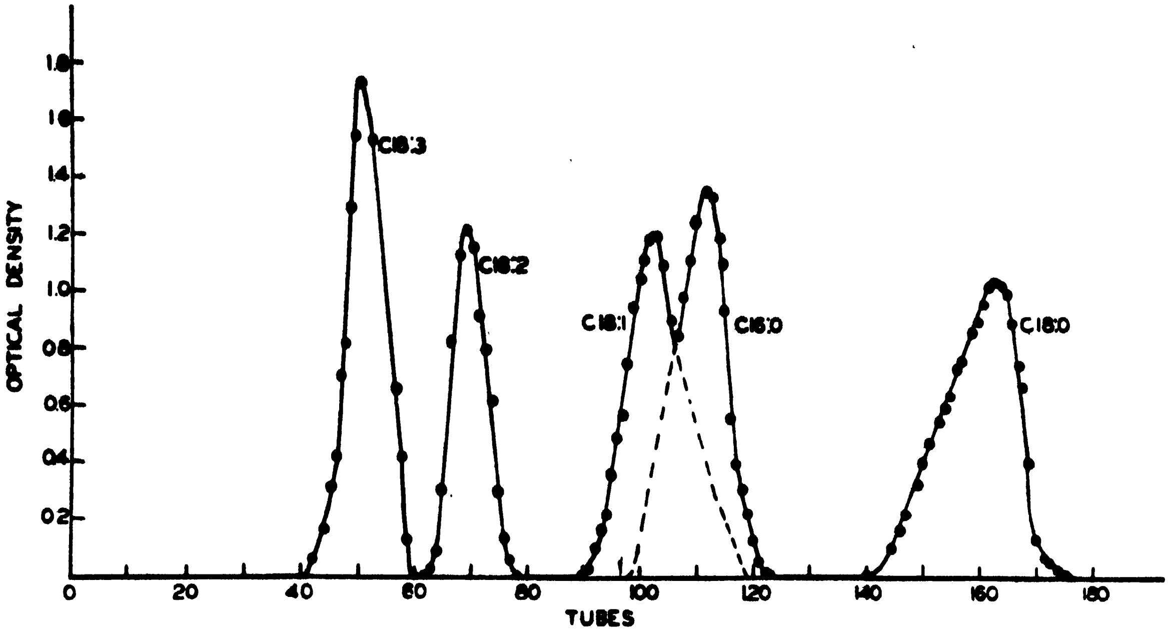

Fig. 7. Isolation of methyl palmitate, stearate, oleate, linoleate, and linolenate by partition chromatography on non-wetting Celite. Concentration of fractions was determined semiquantitatively by charring aliquots on thin-layer plates and measuring the char by densitometer. From Privett and Nickell (21).

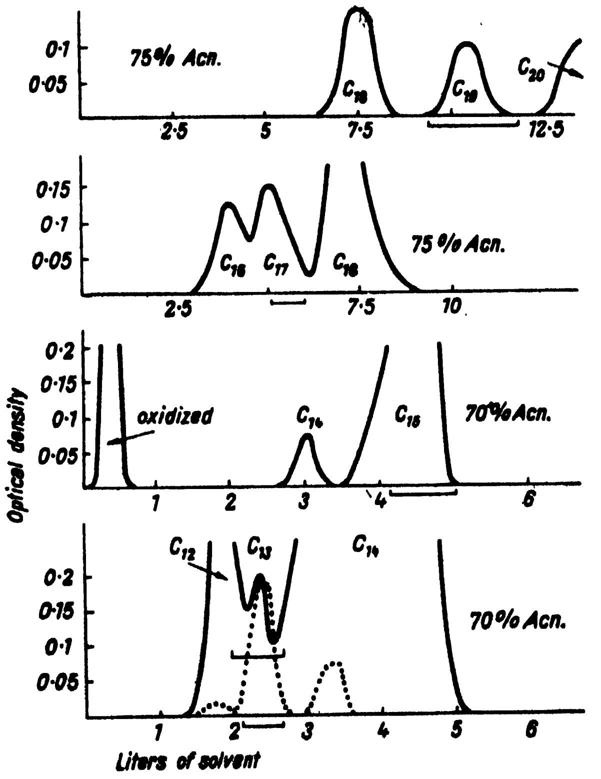

Fig. 8. Separation of methyl esters of fatty acids having odd chain lengths, using partition chromatography on silicone columns. From Gellerman and Schlenk (8).

unsaturated fatty acid esters: for example, two isomers of methyl decosahexaenoate from fish oils.

Silicone columns are likewise very effective in separating closely related acids or esters. Gellerman and Schlenk (8) have used silicone columns to isolate odd chain acid methyl esters from menhaden oil. They chromatographed selected fractions from a distillation of methyl esters from menhaden oil, monitoring the chromatographic fractions by paper chromatography, and demonstrated the presence of 13, 15, 17, and 19 carbon fatty acids in the oil to the extent of 0·09, 0·65, 0·6, and 0·05 per cent respectively. The acids so isolated were shown to be at least 99 per cent pure by gas chromatography. Their work is illustrated in Fig. 8.

Paper chromatography

Separation of fatty acids or their derivatives by paper chromatography has been developed principally by two schools. Schlenk *et al.* (22) used silicone paper and stained the developed papers with iodine or iodine cyclodextrin to reveal the lipids. Kaufmann's laboratory, using undecane-treated paper, commonly detects the spots by converting the fatty acids to heavy metal salts, which are then detected by color reagents (3, 24). An example of the former is given in Fig. 9. Paper chromatography is rapid and has several uses. Perhaps its simplest use is as a test of purity. It may be used as a monitoring device to test the separations achieved on a larger scale by another technique, as shown in Fig. 4. Paper chromatography may also be made quantitative. Mangold has methylated fatty acids with radioactive diazomethane, and determined the density of radioautographs of the developed

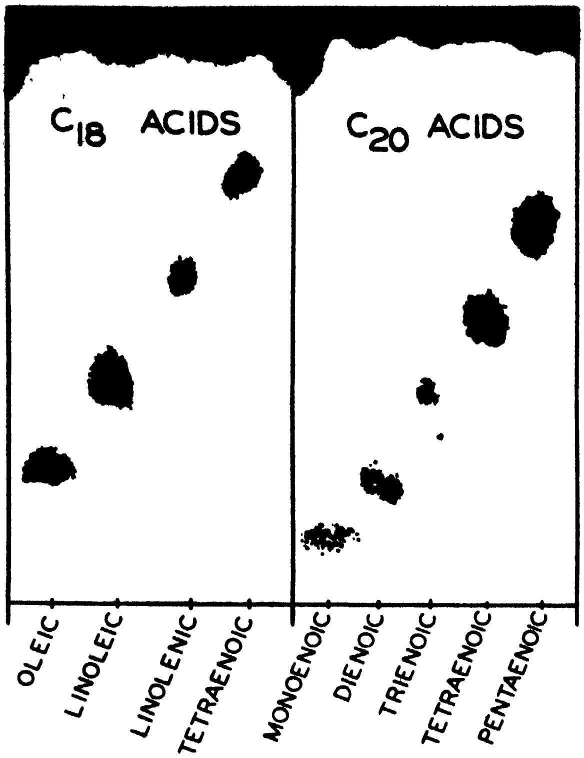

Fig. 9. Separation of unsaturated fatty acids by paper chromatography (5, 22).

paper chromatograms (23). Kaufmann and Budwig used salts of radioactive cobalt to quantitate separations of fatty acids.

Chromatography on glass paper

This modification of paper chromatography introduced by Dieckert and Reiser (25) has this advantage over conventional paper chromatography, that caustic reagents can be used for the demonstration of the separated spots. Usually the chromatogram is sprayed with sulfuric acid, and then heated to char the carbonaceous components. The glass papers may be impregnated with adsorbent materials to achieve specific separations. The method is extremely rapid in routine use, a separation being accomplished and made visible in as little as 10 minutes. Quantitation can be achieved via glass paper chromatography, and a method for determination of plasma cholesterol has been devised by Swartwout *et al.* (26). It appears that any separation which can be performed qualitatively on glass paper can be converted to a quantitative method. This technique should have many applications in the analysis of fish lipids.

Thin-layer chromatography

Adsorption chromatography on thin layers of silicic acid, introduced by Stahl (27), in many ways resembles paper chromatography in its manipulation. A slurry of silicic acid (or some other adsorbent) is spread uniformly on glass plates, dried, and activated. Sample spots are developed by either ascending or descending elution, and the separated spots made visible by a variety of reagents. Mangold and Malins (28) were the first to reveal the high potential of this technique for the separation of lipids. In my opinion, the importance of this method to lipid chemistry is equal to that of gas chromatography.

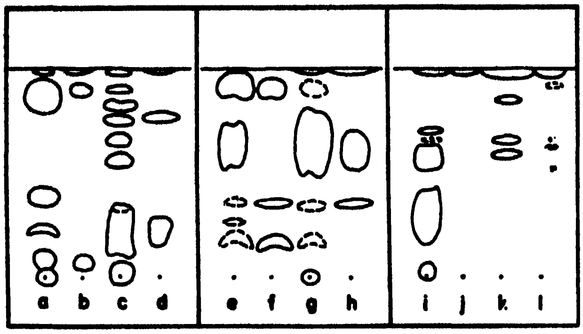

Fig. 10. Separations achieved by thin-layer chromatography: (a) *lanolin;* (b) *oleyl alcohol, cholesteryl palmitate and squalene;* (c) *soupfin shark liver oil;* (d) *tristearin, vitamin A palmitate, and squalene;* (e) *ratfish liver oil;* (f) *batyl alcohol, vitamin A and batyl distearin;* (g) *basking shark liver oil;* (h) *vitamin A, tristearin and squalene;* (i) *castor oil;* (j) *squalene;* (k) *olive oil;* (l) *tristearin. The order of mention is from bottom up. Dotted lines indicate minor constituents. From Mangold and Malins (28).*

Lipid classes that differ in degree of polarity are easily separable. With refinements of technique, even members of a class can be separated. Figure 10 shows a few typical separations. Privett and Blank (29) have adapted the method to the quantitative analysis of mono-, di- and triglycerides. Vioque and Holman (30) have developed a method for the measurement of lipid components containing ester groups based upon thin-layer chromatography and colorimetric measurement of the hydroxamates of the components.

Thin-layer chromatograms (and glass paper chromatograms) can be used for rapid small-scale tests of adsorbents or solvent systems in column chromatography. They may be used to test the purity of products or fractions from other separations. They may be used as monitors of larger fractionations. The quantity of solute in aliquots of fractions from a chromatogram has been determined by charring on thin-layer plates (Fig. 7).

Gas chromatography

Gas chromatography, perhaps more than any other technique, has been responsible for the recent impetus in lipid research. The separations achieved by it are remarkably clear-cut, and the method can be adapted to a wide variety of analytical problems. Any substance that will vaporize without appreciable decomposition can be separated and measured.

The literature on the development of this method and on its application to lipids is voluminous (31). We can give here only a few examples of its application to fish oils. Farquhar *et al.* (32) have made the most complete

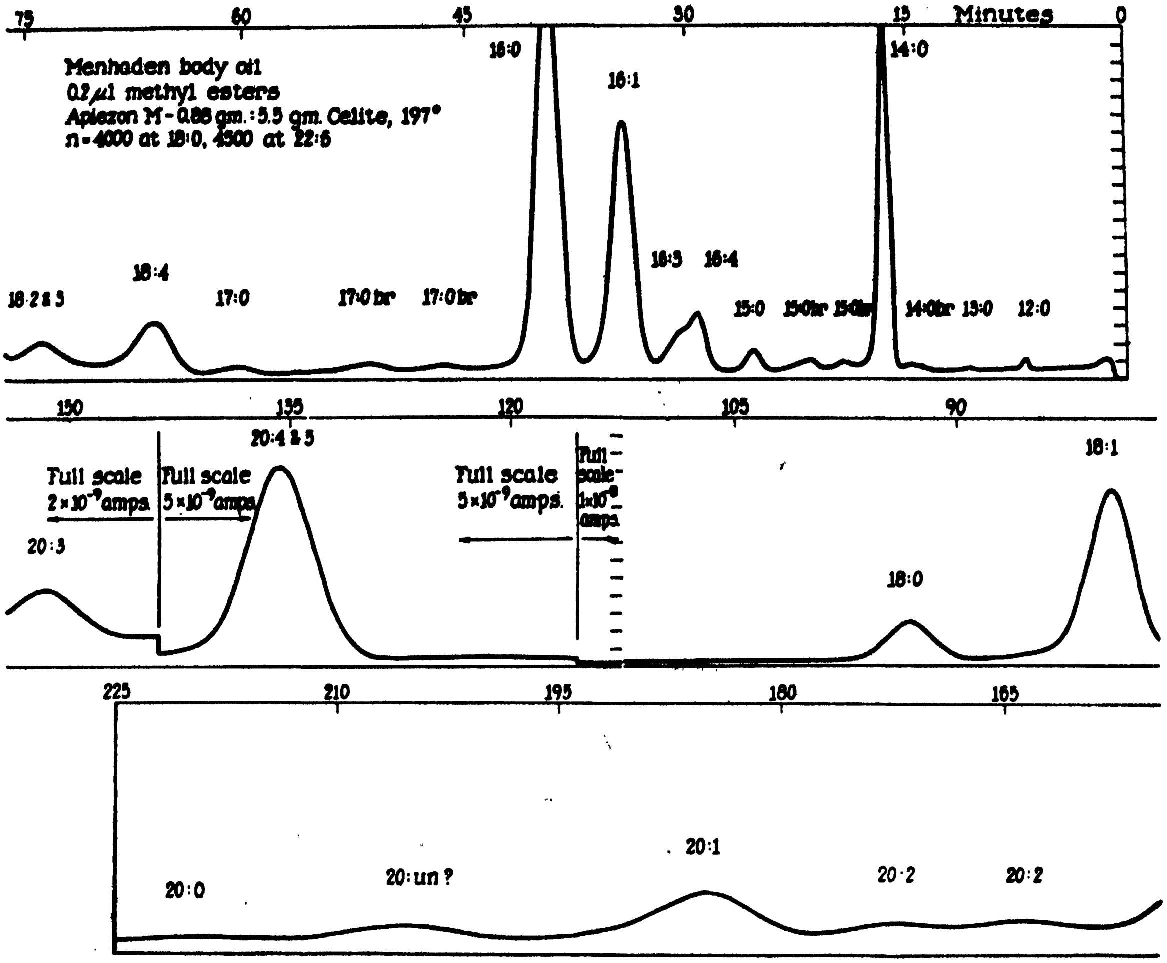

Fig. 11. Gas chromatography of methyl esters of menhaden body oil on Apiezon M. From Farquhar et al. (32).

analysis of the fatty acids of a fish oil. They detected a variety of branched and unsaturated fatty acids, and determined the structures of several of them. By their chromatographic systems they detected approximately forty different fatty acids in menhaden oil. An example of one of their chromatograms is seen in Fig. 11.

Blomstrand and Gürtler (33) have applied gas chromatography to the separation of glyceryl ethers as their acetates, and Malins (34) has used gas chromatography of the aldehydes from the lead tetracetate oxidation of glyceryl ethers for the characterization of the alkoxy diglycerides present in dogfish liver oil. Lambertsen and Holman (35) have studied the composition of the hydrocarbons of fish oil, using gas chromatography. They found as many as 20 hydrocarbons that appeared to be present as groups or families which increased or decreased together from species to species. Pristane and squalene were prominent. New and other constituents of the nonsaponifiable matter should be readily separable with the high temperature columns and temperature-programming equipment now available. The native triglycerides are still somewhat of a problem; but Huebner (36) has separated glycerides as high as trimyristin in gas phase equipment. The applicability of the techniques to fish oils has certainly not been exhausted. Gas chromatography and thin-layer chromatography make a particularly powerful combination of methods for characterization of lipids. Because both require only small samples, separated spots on thin-layer chromatograms can be scraped off and subjected to gas chromatography. Conversely, fractions from a gas chromatogram can be captured and subjected to thin-layer or paper chromatography.

Conclusion

Whereas a decade ago a dearth of discriminating methods for fat analysis existed, we now have a great variety of good techniques for preparation and analysis of lipids. These permit choice, depending upon sample size and type of separation desired. These methods are all applicable to fish oil analysis, and merely await application by scientists concerned with the biochemistry of fish and the chemistry of fish products.

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RELATIONSHIP BETWEEN PROCESSING TECHNIQUES AND THE AMOUNT OF VITAMINS AND MINERALS IN PROCESSED FISH

by

HIDEO HIGASHI

Fish is a rich source of vitamins and minerals for both man and domestic animals. The amounts of these nutritive substances contained in fish, however, vary according to biological factors such as species, age, and the anatomical part of the fish. Moreover, processing techniques affect the stability level of vitamins. It is therefore necessary to determine the extent of loss of vitamins in fish from an initial level for each processing technique.

As a raw material for human consumption, an individual fish may roughly be divided into edible and non-edible parts, the latter usually being discarded before cooking. In a large-sized fish, for instance, the non-edible portion may include the head, fins, viscera, bones and scales. It has been shown, however, that many of the vitamins and minerals of nutritive value are more abundant in the non-edible portion. Furthermore, vitamins and minerals in the edible part are not always very constant in quantity, varying according to the different parts of the fish body. Therefore, a processing technique may often exert an effect upon the amount of the nutritive elements in a product, even when only the edible portion is used.

In fresh fish, nearly all vitamins are found in the edible portion, though the level of concentration differs with the species. Generally speaking, however, most of the fat-soluble vitamins do not present a significant loss in quantity during processing. It is during storage that salted or frozen products show a considerable loss in vitamins due to oxidation. The use of an antioxidant is a very effective preventative, unless the oil contents in fish are large. Then the use of an antioxidant may sometimes prove uneconomical.

Water-soluble vitamins in fish may sometimes be lost through decomposition by heating, or in extraction by water or a salt solution. Nevertheless, this characteristic can be turned to advantage by enhancing the nutritive value of fish solubles in food for domestic animals by collecting water-soluble vitamins as much as possible from the raw material.

In Japan, where the consumption of fish as food is the highest in the world, there are many processing techniques, and there is great interest in biochemical changes in vitamins and minerals during processing. Some of the studies made concerning processing factors responsible for changes in these nutritive elements of fish are described in this paper.

LE RAPPORT ENTRE LES TECHNIQUES DE TRAITEMENT ET LA TENEUR EN VITAMINES ET EN MINERAUX DANS LE POISSON TRAITE

Le poisson est une grande source de vitamines et de minéraux et pour l'homme et pour les animaux domestiques. Cependant, les valeurs de ces substances nutritives contenues dans le poisson sont variables en fonction de facteurs biologiques tels que l'espèce, l'âge et les zones anatomiques du poisson. Les techniques de traitement affectent d'autre part le niveau de stabilité des vitamines. Il est donc nécessaire de déterminer la volume des vitamines qui est perdue dans le poisson à partir de leurs niveaux initiaux dans chaque technique de traitement.

En tant que matière première pour la consommation humaine, un poisson inidividuel peut être divisé simplement en partie consommable et partie non-consommable; celle-ci étant généralement jetée avant la cuisson. Pour un gros poisson, par exemple, la partie non-consommable peut comprendre la tête, les nageoires, les viscères, les arêtes et les écailles. On a montré, cependant, qu'un grand nombre des vitamines et des minéraux de haute valeur nutritive sont plus abondants dans les parties non-consommables. En outre, les vitamines et minéraux de la partie consommable ne sont pas toujours répartis en quantités uniformes dans le corps du poisson. De ce fait, la quantité d'éléments nutritifs d'un produit peut être variée selon la technique de traitement, même si ce produit est préparé avec seule la partie consommable du poisson.

Dans le poisson frais, presque toutes les vitamines existent dans la partie consommable, bien qu'à un niveau de concentration différent selon les types. Cependant, la plupart des vitamines liposolubles ne présentent généralement pas une perte quantitative appréciable au cours du traitement. C'est pendant l'entreposage que les produits salés ou congelés présentent une perte considérable de vitamines due à l'oxydation. L'utilization d'un antioxydant est très efficace pour prévenir la perte de vitamines, à moins que le poisson ait une forte teneur en huile. Dans ce cas, l'utilisation d'un antioxydant peut se révéler parfois comme peu économique.

Les vitamines hydrosolubles du poisson peuvent être quelquefois perdues à cause de la décomposition par la chaleur ou de l'extraction par l'eau ou par une solution saline. Cependant, cette perte caractéristique peut devenir un avantage aux mains de l'homme pour élever la valeur nutritive des solubilisés de poisson utilisés dans l'alimentation des animaux domestiques, en cherchant à recueillir, depuis les matières brutes, le plus possible des vitamines hydrosolubles.

Au Japon, où la consommation de poisson est la plus importante du monde, il existe de nombreuses techniques pour le traitement du poisson; et les changements biochimiques en vitamines et en minéraux, résultant de la technique du traitement, suscitent un grand intérêt. On décrira quelques études effectuées sur les facteurs de traitement responsables des modifications de ces éléments nutritifs.

RELACION ENTRE LAS TECNICAS DE ELABORACION Y LA CANTIDAD DE VITAMINAS Y MINERALES EN EL PESCADO TRATADO

El pescado es una fuente importante de vitaminas y minerales para el hombre y para sus animales domésticos. Las cantidades de estas substancias nutritivas en el pescado varían de acuerdo con factores biológicos como la especie, edad y parte de la anatomía de que procedan. También, las técnicas de fabricación influyen en la estabilidad de las vitaminas. Por esto es necesario determinar la pérdida de vitaminas a partir de la concentración inicial, en cada una de las diversas técnicas de elaboración.

Como materia prima para el consumo humano el pescado puede dividirse en una parte comestible y otra no comestible, la cual se desecha generalmente antes de la cocción. En el caso del pescado grande, la parte no comestible puede comprender cabeza, aletas, vísceras, espinas y escamas. Se ha demostrado que muchas vitaminas y minerales de valor nutritivo abundan más en las partes no comestibles. Asimismo, las vitaminas y minerales en la parte comestible no se encuentran siempre en igual proporción en las diversas partes del cuerpo, y de aquí que un procedimiento de elaboración ejerza en la cantidad de elementos nutritivos del producto, aun cuando sólo se emplee la parte comestible.

En el pescado fresco casi todas las vitaminas se encuentran en la parte comestible, aunque la concentración varía con la especie. En general, casi todas las vitaminas liposolubles no se pierden en cantidades sensibles durante la elaboración; pero durante el almacenamiento los

productos salados o congelados pierden muchas por causa de la oxidación; el empleo de antioxidantes es muy eficaz para evitarlo, a menos que el pescado contenga mucho aceite, en cuyo caso el empleo de antioxidantes puede, en ocasiones, ser antieconómico.

Las vitaminas del pescado solubles en agua pueden perderse algunas veces por descomposición al calentar o por extracción con agua o una solución de sal. Sin embargo, se puede aprovechar esta característica para reforzar el valor nutritivo de los solubles de pescado como piensos para los animales domésticos, recogiendo el mayor número factible de vitaminas hidrosolubles a partir de las materias primas.

En el Japón, que es el pais del mundo donde se consume más pescado, se conocen muchos procedimientos para elaborarlo e interesan mucho los cambios bioquímicos de vitaminas y minerales causados por la elaboración. Algunos de los estudios realizados hasta ahora de los factores de la elaboración causantes de los cambios de estos elementos nutritivos del pescado se describen en esta comunicación.

IN Japan the consumption of fish as a source of protein supply is probably the highest in the world. Annual total fish landings in Japan lead world fish production; those for the years 1953–59 are shown in Fig. 1 (1). In order to secure a maximum utilization for human consumption, these catches are processed in innumerable ways, as shown in Fig. 2, which also gives annual production. Except for salted fish and boiled-dried fish, most of these products are manufactured after removing the head, fins, viscera, bones and scales. The amounts of vitamins and minerals contained in the processed food vary according to processing techniques. The present paper deals with: (i) difference in vitamin content in different anatomical parts and species; (ii) loss of vitamins due to processing, and preventive measures; and (iii) mineral content in various fishes.

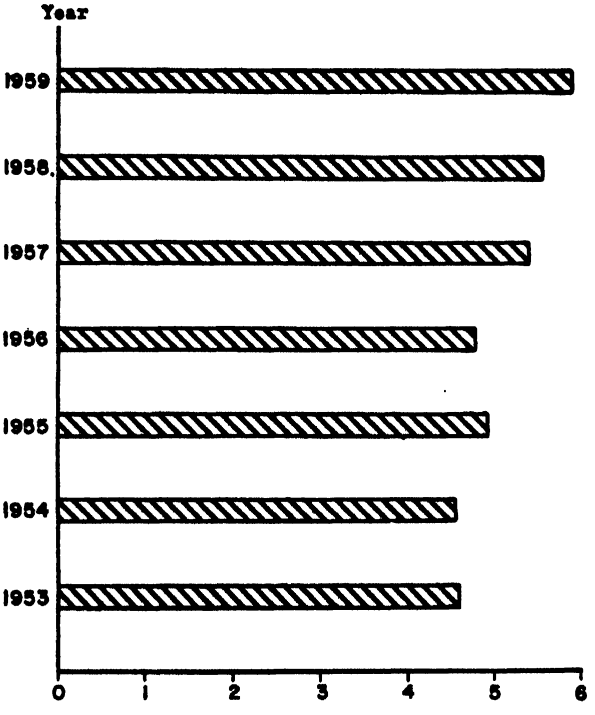

Fig. 1. Yearly total catches excluding whale.

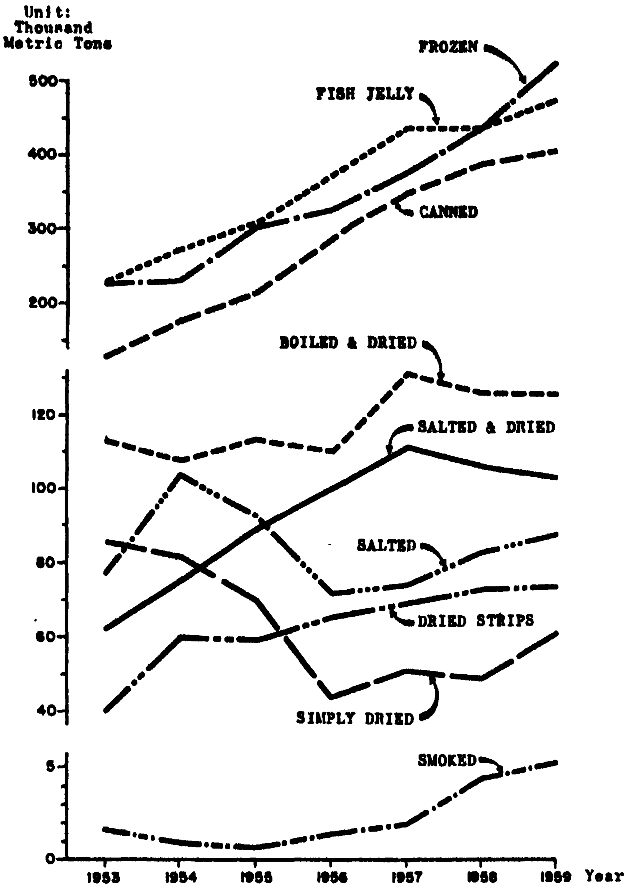

Fig. 2. Production of processed marine products for marketing.

1. Vitamin content of fish as raw material for processed food

In processing fish into food, the first step is to divide an individual fish body into an edible and a non-edible part. Since the amounts of vitamins contained in the tissues of fish vary from part to part, it is not feasible to compute the amount of vitamins simply by the weight ratio between the edible and the non-edible part. Of the non-edible portions of fish the viscera usually contain vitamins at a much higher level than the muscle, though there are exceptional cases depending on kind of vitamins as well as the species of fish.

1.1. Vitamin A and D. In a majority of species, larger portions of vitamin A and D are found accumulated in the viscera—particularly the liver—than in any other part of the body (2). In a few cases, however (i.e. lamprey, eel, conger eel) the flesh contains a significant portion of total vitamin A in the body (3, 4). Table I indicates the distributive ratio of vitamin A between the flesh and the viscera of these species and of average fish, taking dog salmon and skipjack as examples. Therefore, when the

TABLE I

Distribution of vitamin A between flesh and viscera

Species	*Flesh* (%)	*Viscera* (%)
Dog salmon	7	93
Skipjack	1	99
Lamprey	38	62
Eel	81	19
Conger eel	77	23

viscera are discarded, as is the usual practice when processing, very little vitamin A remains in the edible portion. However, the lamprey, eel and conger eel contain more vitamin A in the flesh than in the viscera, and at a high level (Table II). It is possible for man to take a considerable amount of vitamin A by using these species as food. In fact, the Japanese have appreciated these fish as a kind of tonic food for hundreds of years. The cooking process for eel and lamprey is perhaps unique to Japan. After the fish are cut open, the viscera and vertebra are removed. The flesh is skewed on bamboo sticks broiled over a charcoal fire, and served with a special condiment. In the case of the eel, the viscera are also broiled in a similar manner or cooked into a soup. Thus almost all vitamin A contained in the eel is utilized as food. Lamprey flesh contains more vitamin A than any other species, though the quantitative ratio of vitamin A in the flesh to the total amount in the body is lower than in the eel, because of a markedly large amount of vitamin A contained in the alimentary canals of the lamprey (5).

TABLE II

Vitamin A content in flesh of vitamin A rich species

Species	*Vitamin A Content (I.U. per 100 g. of flesh)*
Lamprey	14,000–63,000
Eel	1,000–12,800
Conger eel	1,000–2,000

Some species of sharks contain abundant vitamin A in their flesh. In the dog-fish, for instance, the level is 1,000–3,000 I.U. and in the deep sea shark (*Heteroscymnus longus*) 5,700–27,000 I.U. per 100 g. of flesh. However, the ratio of vitamin A in the flesh to the total amount of the body is insignificant, because of markedly rich vitamin A contained in the liver.

In tunas, vitamin A content is high in the viscera, but low in the flesh. Particularly the white meat of tunas presents vitamin A as low as a few fractions of the content in the dark meat (6). It should be noted, therefore, that a very limited amount of vitamin A is utilized in most canned products based on frozen yellowfin or skipjack, since the dark meat as well as the viscera, heads, bones and fins are discarded.

As in the case of vitamin A, the fish liver usually contains vitamin D at a high concentration, but the flesh not so much. The vitamin D content in the flesh is dependent on the species of fish. For instance, the yellow tail and flatfish contain vitamin D in the flesh but at low level, while the sardine, saury and mackerel have it at a fairly high level (7, 8).

1.2. Water-soluble vitamins. Some important members of water-soluble vitamins which exist in fish include vitamin B_1, B_2, B_6, niacin, folic acid, pantothenic acid and vitamin C. Their distribution in the tissues of fish is entirely different from the distributive pattern of vitamin A and D. These water-soluble vitamins, though they are appreciably contained in the viscera (particularly the liver, pyloric appendages and kidney), do not show quantitative discrepancy so remarkably as do vitamin A and D. Therefore, more than one half of the total amount of water-soluble vitamins in the body of fish are accumulated in the flesh (9, 10, 11, 12, 13, 14, 15).

In some processing operations, dark meat is separated as inedible from white meat because of the obnoxious smell. Nevertheless, we must remember that dark meat is appreciably more water-soluble than white meat. Take the mackerel, jack mackerel, and skipjack for instance. In Table III the quantitative comparison of water-soluble vitamin between the white meat and the dark meat of these fishes reveals that there are two groups of vitamin: one including vitamin B_1, B_2, B_{12}, pantothenic acid and folic acid; the other, vitamin B_6 and niacin. The former group occurs much more plentifully in the dark meat than in the white meat, while the latter is contained in the dark meat at nearly the same level as in the white

TABLE III

Contents of water-soluble vitamins in flesh

Species	*Part of Flesh*	B_1 *γ/g.*	B_2 *γ/g.*	B_6 *γ/g.*	B_{12} *γ/100g.*	*P.A. γ/g.*	*F.A. γ/100g.*	*Niacin mg./100g.*
Mackerel	White	0·8	0·3	14	0·9	1·6	1·9	21·4
	Dark	8·8	2·8	10	8·0	16	5·8	19·8
Horse mackerel	White	1·5	0·8	—	0·3	—	—	—
	Dark	3·3	7·8	—	7·8	—	—	—
Skipjack	White	0·6	0·3	10·5	2·5	—	—	24·5
	Dark	5·2	6·9	9·0	16·5	—	—	12·2

P.A.: Pantothenic acid F.A.: Folic acid

TABLE IV

Riboflavin content in skin

Species	*Part of skin*	B_2 *content* (*γ/g.*)
Flatfish	Eyed side	65·3
	Blind side	1·04
Starry flounder . . .	Eyed side	22·3
	Blind side	0·85
Yellowfin tuna	—	11–65
Albacore	Dorsal side	133·9
	Ventral side	59·3
Mackerel	Dorsal side	12·0
	Ventral side	3·1

meat. In the processing operation, therefore, the removal of the dark meat would result in a substantial loss of the first group of vitamins; but it loses the latter group members only in the weight ratio of the dark meat to the white.

An appreciable amount of vitamin B_2 is contained in the skin of the fish, particularly black skin on the dorsal side or the eyed side on the case of flatfish (16). The skin of tunas is very seldom used for food though it is rich in vitamin B_2 content (Table IV) (17).

2. Loss of vitamins due to processing operations

In the preceding section an account has been given of the quantitative ratios of vitamin members that are discarded along with inedible parts at the first stage of processing. Destruction of vitamins which takes place in the edible portion of fish in further courses of processing varies in rate depending on the processing technique employed. A description will now be given of the vitaminological aspects for some representative forms of Japanese fish products.

2.1. Canned fish. Vitamin B_1 and vitamin C contained in fish material are destroyed to a substantial extent during canning. Even the process of sterilization normally used in the industry is responsible for the destruction. However, the other vitamins are left nearly intact at this stage of the canning process (Table V) (18). The amounts of vitamin A and D contained in canned fish are very often found at a level markedly lower than in fresh fish. Nevertheless, these cases are attributable to the destruction which takes place during a cold storage period of the products rather than to the pressure sterilization applied. A serious problem met in the canning process of tunas is the occasional occurrence of blue meat, which depreciates the market value of the product. It has been known that blue meat occurs when the raw material contains vitamin B_6 and B_{12} and phosphorus in abnormal proportions to other nutritive components (19). A suggestion is to supplement vitamin C and niacin to raw material at the packing stage. Addition of these members inhibits occurrence of blue meat in canned tunas and enriches the vitamin content to some extent (20) Use of vitamin C and niacin along with phosphate is markedly effective for preventing the brown discoloration that occasionally takes place in canned whale meat based on the salted material.

2.2. Simple dried fish. More than 5,000 metric tons of fish are processed into simple dried form, the major species of fish used being the sardine, cod, Alaska pollack and squid. In the latter three species low oil content precludes such a serious oxidation of the oil as might impair the quality of the product and thus affect the market value. In the sardine, however, discoloration of the products occurs on account of oxidation of the abundant oil contained in the raw material. These simple dried fish products contain a considerable amount of water-soluble vitamins, but little or no vitamin A. The lamprey has been in use for filling the vitamin A deficiency. For that purpose a round fish is simply dried in the shade for some days. Often the dried lamprey is stored for months. Yet a large amount of vitamin A still remains in the product (4). In samples of dried lamprey brought to the author's laboratory, the oil content was measured at levels of 30–50 per cent, with the vitamin A concentration in the oil at 770–6,300 I.U./g.

2.3. Boiled and dried fish. Important raw material for boiled and dried fish include sardine, mackerel and jack mackerel. They are boiled round in water and then dried in the sun. As an important seasoning for soup or sauce, the products of small-sized fish are used whole, and

TABLE V

Change of B-vitamins in tuna during canning and storage

	Raw meat /100 g.	*Steamed meat /100 g.*	*Retention during steaming %*	*Storage period (months)*	*Canned product*		*Retention during pressure sterilization %*	*Retention during whole procedure %*
					/can	*/100 g.*		
Thiamine (γ)	114	76	60·1	0	61	30	48·8	29·3
				1	64	31	50·6	30·4
				3	55	26	43·9	26·4
				6	51	24	40·3	24·2
Riboflavin (γ)	56	54	87·6	0	86	41	96·4	84·4
				1	83	40	93·5	81·9
				3	86	42	97·4	85·3
				6	87	42	98·0	85·8
Niacin (mg.)	15·9	15·8	89·6	0	25·3	12·2	97·0	86·9
				1	25·7	12·8	102·4	91·8
				3	26·0	12·5	99·5	89·2
				6	27·5	13·2	105·4	94·4
B_{12} (γ)	0·7	0·7	93·3	0	1·2	0·6	103·0	96·1
				1	1·1	0·5	100·4	93·7
				3	1·3	0·6	111·8	104·3
				6	1·2	0·6	104·1	97·0

large-sized ones in sliced form. Some portions of water-soluble vitamins are dissolved at the stage of boiling, and nearly all fat-soluble vitamins are lost due to oxidation during drying and storage. For the purpose of minimizing the oxidation, some kinds of antioxidant have been used in Japan for about ten years. They are, for instance, butylated hydroxyanisol, dibutyl hydroxytoluene.

Dried strips of skipjack are called "Katsuo-bushi". Although they may be also regarded as a kind of boiled and dried product used for seasoning, a more deliberate procedure is required for processing. After boiling and smouldering, the material is subjected several times to moulding. At the stage of boiling, a large quantity of water-soluble vitamins is removed from the flesh into the cooked liquid, which is sometimes prepared by evaporation into a condensed extract and served as seasoning. Recently efforts have been made to utilize the material which contains oil at a level higher than normally allowable for processing them into boiled and dried fish or dried strips of skipjack as seasoning. For this purpose, the oil is extracted with hexane. The material thus treated is subjected to boiling or steaming, and then drying. This technique is now at an experimental stage.

2.4. Salted or smoked fish. As elsewhere, salted fish are marketed with or without drying. To this end, either brine salting or dry salting is the usual practice. But destruction of water-soluble vitamins in these processes is inevitable, while later loss of fat-soluble components by oxidation occurs during storage. As in boiled-dried fish, the use of antioxidant has been introduced to some extent.

In the case of smoked fish, impairment of the water-soluble vitamins to some extent is also an unavoidable consequence of brine salting. However, smoking is fairly effective for precluding oxidation of lipids in the products.

2.5. Fish jelly products and fish sausage. The various types of fish jelly products in Japan may attract the person interested in fish as food (Fig. 2). Important types of fish jelly products include "chikuwa", "kamaboko", "hampen" and fish sausage. They are prepared by making use of characteristic behaviors of myosin contained in the fish meat. In preparation, the meat washed with water is kneaded with salt (about 3 per cent by weight). It is then shaped into various forms, and steamed or fried in vegetable oil according to the type of product required. The products are of jelly-like consistency. In the early stage of manufacture, water-soluble vitamins are washed away. Furthermore, in cases of "hampen", "chikuwa" and "kamaboko", fat-soluble vitamins retained till a final stage are almost entirely destroyed by bleaching with hydrogen peroxide, as practised for commercial reasons. It has been strongly recommended not to use the bleacher in these products.

Fish sausage, the latest type of fish jelly product, was introduced to the Japanese in the early 1950s. Although the processing technique is based on an idea modified from that of "kamaboko" or similar products, there are many reasons which induce a wide range of consumers to prefer this product to the others. The production of fish sausage, which has increased year by year, now reaches about 80,000 metric tons a year, leaving the old-fashioned products far behind. In a factory, the material, prepared with a few modifications from usual procedures for fish jelly products, is stuffed into a casing of water-and-oil-repellent synthetic film, such as rubber hydrochloride or vinyliden chloride. Then it is twice cooked at about 85°–100°C, first for an hour and then for 1 minute after cooling. A finished piece of the product weighs 120–150 g. Usually they can be stored at room temperature for about 1 month, a much longer shelf life than for other fish jelly products. Since additives of fat-soluble vitamins into the fish sausage are hardly decomposed by cooking, it is recommended that the products be enriched with vitamin A at 3,000 I.U. per piece.

Use of protein curd as additive was first suggested about 1958 for manufacturing some fish jelly products. The protein curd now in use is prepared from soy bean flour defatted at a low temperature. Production of fish jelly products prepared in this way is increasing, because they not only taste good but have an advantage in precluding oxidation of the product.

2.6. Fermented fish products. To the Japanese, fermented fish products are most familiar by the name "shiokara". Taken along with rice wine, these indigenous forms of food have been appreciated as appetizers over the centuries. They are prepared by mixing 15–30 per cent of salt with the viscera of fish such as the stomach, intestine, pyloric appendages, liver and kidney. In the case of the squid, which is an important material for a specific type of product, the sliced meat of the trunk and tentacles is also used together with the liver. In processing, water-soluble vitamins do not decrease so notably from the initial levels contained in visceral materials as do fat-soluble members. Nutritive components of some of the major fermented fish products in Japan are shown in Table VI.

2.7. Fish meal and fish solubles. In Japan both fish meal and fish solubles are produced in large quantities; a major portion of these is used as food for domestic animals. Until the early 1930s, an attempt to use fish meal for human consumption in some way or other had been greatly encouraged. Later, however, the food preference particular to the Japanese made it difficult to find any way of utilizing a large amount of fish meal as human food. In the years around 1945, another technique was proposed, to process fish meal into a kind of paste by moulding the material and fermenting it together with salt and water. It has been confirmed that moulding intended for removal of fat induces ergosterol to form in the fish meal material which did not contain it initially (21). Fish paste could be industrialized, but for the fish production cost and the limited daily consumption to be expected.

Since material for fish meal undergoes steaming, pressing and drying, both fat-soluble and water-soluble vitamins are separated into waste water. The rate at which water-soluble vitamins are removed in processing

TABLE VI

Analysis of Japanese fermented products

	Katsuo shiokara (*Viscera of skipjack*)	*Ika shiokara* (*Viscera and meat slices of squid*)	*Konowata* (*Viscera of sea cucumber*)	*Ami shiokara* (*Mysis of crustacea*)
Moisture %	62·5	67·3	77·5	55·5
Crude protein %	12·8	14·6	9·8	12·2
Crude fat %	2·20	0·99	1·27	0·53
Crude ash %	21·9	16·0	12·4	32·1
Minerals				
NaCl %	20·5	11·7	10·3	29·2
Ca mg. %	178	82	85	512
P mg. %	171	279	168	267
Fe mg. %	3·0	2·5	3·6	2·8
Vitamins				
A I.U./100 g.	130	100	90	20
Car./100 g.	—	—	60	—
B_2/100 g.	2·66	2·86	5·29	0·97
B_{12}/100 g.	0·56	0·98	12·5	4·22
P.A./100 g.	3·5	3·18	11·3	8·0
F.A./100 g.	37·5	7·0	43·8	14·75

Car.: Carotene. P.A.: Pantothenic acid. F.A.: Folic acid.

operations varies according to freshness of raw material as well as the kind of vitamins contained. Even in a normally acceptable quality of material for fish meal, such vitamins as B_1, B_2 and C are hardly left in the finished product, while other members, including B_6, B_{12}, pantothenic acid and folic acid, remain there in great amounts. Table VII indicates levels of some of the nutritive components in fish meal and solubles assessed at the author's laboratory.

TABLE VII

Nutritive elements of fish meals and fish solubles

	Fish meal				*Fish soluble*			
Raw material	(*a*)	(*b*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)	(*g*)
Moisture % . . .	7·1	11·8	12·0	11·9	41·8	40·4	40·7	42·6
Crude fat % . . .	4·8	6·9	8·1	13·1	7·7	11·2	6·6	4·1
Crude protein % . .	66·5	54·4	53·2	56·1	44·9	38·2	41·6	38·8
Crude ash % . . .	16·9	23·8	21·7	14·1	3·4	4·6	10·1	10·8
Minerals								
Ca mg. % . . .	5280	7660	6770	4540	27·3	65·4	35·2	29·8
P mg. % . . .	3560	3725	3910	2135	508	768	883	871
Fe mg. % . . .	23·0	76·8	45·5	44·5	44·8	24·7	18·7	20·9
K mg. % . . .	—	—	—	—	20·0	22·5	76·2	—
Na mg. % . . .	—	—	—	—	96	136	280	—
Vitamins								
A I.U./g. . . .	8·8	2·4	3·0	3·4	271	436	33	3
B_1/g.	0·5	7·6	2·0	0·8	0·07	0·04	—	5·4
B_2/g.	2·5	7·5	4·1	3·3	5·6	6·7	3·4	11·3
B_6/g.	7·2	1·8	2·3	1·4	6·6	1·6	13·0	15·0
Niacin mg./100 g. . .	—	—	—	—	14·7	11·3	27·1	50·0
P.A./g.. . . .	6·0	6·4	5·6	4·3	25·5	24·5	15·0	49·5
F.A./100 g. . . .	12	25	88	42	—	—	—	—
Biotin/100 g.. . .	—	—	—	—	80	216	56	43
B_{12}/100 g. . . .	4·8	7·5	5·4	11·0	20·0	20·0	16·0	25·0

Note :

(*a*) Flatfish, cod and Alaska pollack.
(*b*) Alaska pollack waste.
(*c*) Miscellaneous fish.
(*d*) Tuna viscera.
(*e*) Alaska pollack and Atka mackerel flesh mixed with viscera.
(*f*) Cuttlefish, saury, Alaska pollack and salmon flesh mixed with viscera.
(*g*) Cooked liquor of skipjack flesh.
P.A. Pantothenic acid.
F.A. Folic acid.

3. Loss of minerals during processing operations

Fish offer nearly every kind of mineral for man's nutritive requirements. For the Japanese, however, Ca, P and Fe are more important members than the others from the nutritive viewpoint. Particularly, the amount of calcium contained in fish does much to supplement its deficiency, often criticized in comparison with the phosphorus content, in the daily food of the nation. Table VIII has been prepared to indicate the major mineral contents in the edible parts of fish. Evidently large-sized fish, the head, bones and skin of which are removed at an early stage of processing, do not offer the minerals in their edible portion so abundantly as do small-sized fish, crustacean and mollusc. However, some workers are doubtful as to whether or not Ca contained in the shells of crustacean can be efficiently utilized for nutritive purposes. It is certainly without reason that some of these minor species of aquatic animals are processed into a form of Japanese food called "tsukudani". Except a few species of shellfish, these tiny fish, shrimp and mysis, are used round, without removing any part of the body, for a type of "tsukudani". They are boiled down together with soy bean sauce, sugar and some other seasoning. "Tsukudani" based on sea food is rich in mineral content as shown in Table IX, and a great deal, covering many varieties, is consumed all over Japan. It should be added that, when these minor species of fish are processed into food, attention must be paid, not only to assuring the quantity of Ca and P in the product, but also to properly controlling a quantitative rate between both minerals.

TABLE VIII

Mineral contents in edible part of fish and other aquatic animals

Species	*Contents of minerals mg./100 g.* *Ca*	*P*	*Fe*
Yellowfin tuna	2	250	1
Mackerel	5	190	1·8
Cod	9	160	0·4
Sardine	50	240	2
Saury	22	190	3
Pond smelt	750	680	5
Mysis	210	290	11
Clam	60	90	13
Oyster	40	140	8
Shrimp	275	400	4

TABLE IX

Mineral content of "Tsukudani"

Species used	*Form of product*	*Ca*	*P*	*Fe*	*Ca/P*
Cod	Dembu[1]	260	120	5·5	2·8
Goby	Ordinary tsukudani	610	860	0·5	0·7
Pond smelt	Ordinary tsukudani	400	720	5·9	0·6
Ammodytes	Ordinary tsukudani	328	258	5·6	1·3
Skipjack	Kakuni[2]	72	170	7	0·4
Clam	Ordinary tsukudani	220	280	13·6	0·8
Mysis	Ordinary tsukudani	990	260	20	3·8

[1] Fish meat fiber boiled with soy bean sauce, sugar, mirin and water.
[2] Meat boiled, lightly smouldered and cut into dices, then boiled again in soy bean sauce and sugar.

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B-VITAMINS IN FISH AND SHELLFISH

by

OLAF R. BRAEKKAN

B-vitamins in fresh meat of fish and shellfish are here reviewed. The reliability of values reported in the literature, in relation to methods of sampling and analysis, is generally discussed. For the B-vitamins thiamine, riboflavin, niacin, vitamin B_{12}, vitamin B_6, pantothenic acid and biotin, min.-max. values from different studies are summarized. When the available data seemed to justify conclusions with regard to correct averages, such values are given.

Compared with meat, fish and shellfish are found to be good dietary sources of B-vitamins. Thiamine, riboflavin and pantothenic acid are usually present in less concentration than in common meat. Lean fish and shellfish show relatively moderate values for niacin, while most other species may be considered good or even rich sources of this vitamin. Fish is a good source of vitamin B_{12}; the fat fish and the molluscs are very rich sources. Studies made to date show fish to be good sources for vitamin B_6 and biotin.

LES VITAMINES B DANS LES POISSONS, COQUILLAGES ET CRUSTACES

On a considéré les vitamines B dans la chair fraîche de poisson, de coquillage et de crustacé. On a commenté d'une façon générale la confiance qu'on peut avoir dans les valeurs présentées dans la littérature, en fonction des méthodes d'échantillonnage et d'analyse. On a résumé d'après différentes études les valeurs minimum et maximum pour les vitamines B: thiamine, riboflavine, niacine, vitamine B_{12}, vitamine B_6, acide pantothénique et biotine. Quand les données disponibles ont paru justifier les conclusions sur la correction des moyennes, on a donné ces valeurs.

Comparés à la viande, les poissons, coquillages et crustacés se sont révélés être de bonnes sources diététiques en vitamines B. La thiamine, la riboflavine et l'acide panthoténique sont habituellement présents sous des concentrations moindres que dans la viande courante. Le poisson maigre et les coquillages et crustacés ont montré des teneurs modérées en niacine, alors que la plupart des autres espèces peuvent être considérées comme sources bonnes ou même riches de cette vitamine. Le poisson est une bonne source de vitamine B_{12}, dont les poissons gras et les mollusques se présentent comme de riches sources. Les études ont montré jusqu'ici que le poisson était une bonne source en vitamine B_6 et en biotine.

LAS VITAMINAS B EN PESCADO Y MARISCOS

Se han hecho estudios del contenido de vitaminas B en la carne fresca de pescado y mariscos. Se hace un examen general de la seguridad de los índices comunicados en la literatura científica con respecto a los métodos de muestreo y análisis.

Para las vitaminas B tiamina, riboflavin, niacina, vitamina B_{12}, vitamina B_6, ácido pantoténico y biotina se resumen los valores mínimos y máximos de diversos estudios. Cuando los datos disponibles parecen justificar conclusiones relativas a promedios correctos, se dan tales índices.

En comparación con la carne, el pescado y los mariscos son buenas fuentes de vitaminas B. Tiamina, riboflavina y ácido pantoténico están presentes en general en concentraciones más bajas que en la carne. El pescado magro y los mariscos muestran índices relativamente moderados de niacina, mientras que casi todas las demás especies pueden considerarse como fuentes buenas y aun excelentes de esta vitamina. El pescado es una buena fuente de vitamina B_{12} y aun el graso y los moluscos son fuentes muy ricas. Los estudios realizados hasta ahora demuestran que el pescado es una buena fuente de vitamina B_6 y biotina.

THE rapid expansion of vitamin research has not only given information with regard to human requirements of many of the known vitamins, but also the relation of the requirement to the composition and caloric value of the diet. To ensure an adequate supply, not only of the basic food such as protein, fat and carbohydrates, but also of the so-called "protective factors" such as vitamins, it is necessary to have trustworthy tables of the vitamin content of different foods. Many tables have been published in different countries to meet this demand. FAO has also tried to help fill this demand, and issued in 1954 *Food Composition Tables—Minerals and Vitamins*, prepared by Chatfield (1).

With regard to the vitamin content of fish, values reported in the literature are still insufficient, and many more studies are needed to complete the gaps in our knowledge and to verify values reported in the literature. Contrary to the produce of husbandry and agriculture, the fisheries give very varying harvest in different areas of the oceans. The number of species which are utilized are very large, and confusion with regard to names and species is very frequent. Thus vitamin studies in fish have too often emphasized the analysis and omitted a clear definition of the samples (i.e. the species of fish, number of fishes, fishing places, etc.). This makes it difficult to compile and review some of the results in the literature. Generally, only species marketed in countries with somewhat advanced research in the field of vitamins have been analysed for the most important factors. Fortunately, this research is now being made in areas not yet covered by such studies. The importance of sampling and recording of the species in these studies can not be over-emphasized. The problem of the many species utilized in different parts of the world makes it difficult to concentrate the data without the risk of discrimination. Kühnau (2) and Love, Lovern and Jones (3) have compiled vitamin values for fish. Their tables have been of very great value for the preparation of this review. They reported the single results and tabulated the species in alphabetical order. In this review a different approach has been made. Based on the *FAO Yearbook of Fisheries Statistics* (4) the fishes have been treated in main groups of species. The two groups, crustaceans and molluscs, have been combined. The group of aquatic plants was considered outside the scope of this report. Within each main group, the families and species have been reported alphabetically. Attempts have been made to consider mainly species of nutritional importance in which at least 3 B-vitamins have been analysed. The tables report min.-max. values above the line, while average values (which the present author considers fairly representative) are recorded under the lines. It must be emphasized that these are *not* always average values from the findings reported in the literature, but represent values reached by total consideration of all studies related to, respectively, the species and the vitamin in question.

Before the values reported in the tables are discussed, it is necessary to consider a few points with regard to the values as related to methods of analyses and the type of muscles in fishes. Vitamin determinations in fish and fish products have been carried out for as many years as such studies have been performed on food. During these periods the methods employed for the determination of the different B-vitamins have changed considerably. Animal assays based on vitamin-deficient diets and supplementation of standard and samples are unfortunately expensive, and often very difficult to perform with sufficient precision. It may, however, be pointed out that they are important in determining the availability of the vitamins to animals. Chemical methods with fairly good specificity and precision have been introduced for several B-vitamins. Their main disadvantage is the frequent need for isolation of the vitamins, which may be a problem for certain products where related substances may disturb. The introduction of microbiological methods overcame this problem in most instances; but it may be pointed out that the different extraction methods employed may, as for the chemical methods, not be representative for the utilization of the vitamin in animals. The further studies of these methods have pointed to the necessity of a careful consideration of the specificity of the nutritional need of the micro-organism employed. The classic example is the studies of the vitamin B_6-content of food, employing different organisms, which lead to the discovery by Snell *et al.* (5, 6) of the vitamin B_6-group consisting of pyridoxine, pyridoxal and pyridoxamine, which are all equally utilized by animals.

Fish and fish products are most important sources of vitamin B_{12}, which is so important in animal feeding. The specificity, or lack of such, for the different organisms employed in the assay of this vitamin is much discussed. It may be pointed out that the methods employing *Lactobacillus leichmannii*, frequently used in studies on fish, seems sufficiently specific for this type of sample.

Thus Braekkan *et al.* (73) found a direct relationship between the microbiological determination of vitamin B_{12} in herring meal and a fermentation product, and the corresponding values for the liver-storage in chicks and rats. Folic acid has been analysed in a few fish and fish products (7, 8, 9). The specificity of this test has lately been challenged, and the method renounced for official use (10). For this reason values for this vitamin have been completely omitted in the present review.

The dark muscle in fish is usually a superficial lateral muscle; in some species it is also a deep-seated muscle, and in some sharks it is only deep-seated. It has a greatly differing composition compared with the ordinary muscle, and has vitamin values similar to those in the liver. It has been suggested that it has no contractile function, but rather that of an organ (11). Although the amount of dark muscle is often limited, it can form as much as 24 per cent of the total musculature (12). When it is considered that B-vitamin values are more than ten times higher in the dark than in the ordinary muscle, the importance of the sampling and the homogenization of the samples cannot be emphasized enough. Probably many of the variations observed for vitamins in the literature are a direct result of ignorance on this point in earlier studies.

It may further be pointed out that the values in the present review refer to the uncooked edible part of the fish, i.e. the meat as it is used for processing either in the home or in industry. Data for B-vitamins in fish as ready-prepared food would be desirable; but the different processing methods, among others the addition of other foods, make proper evaluation difficult. Ingalls *et al.* (22) found the losses of niacin, riboflavin and thiamine in cooking depended on the temperature and the thickness of the sample. More vitamins were retained in baked fish than in pan-fried fish. Riboflavin retention was higher in pan-fried fish than for the two other vitamins studied. They also pointed out a loss of 50 per cent of each vitamin when the fish was fried in deep fat. These problems need further study before final conclusions can be drawn. Generally the protein of the fish coagulates during processing in such a way as to hinder extensive extraction of B-vitamins. If not cooked too long, and if not too much water is used, the values for cooked fish will correspond fairly well with the values reported for fresh fish (42).

In Table I are summarized values for B-vitamins in fresh water fishes. Although the world catch amounts to approximately 15 per cent of the world grand total, only limited efforts seem to have been made to determine their vitamin content. Thus China (Mainland), Africa, Indonesia and U.S.S.R. catch more than half of the grand total, though few studies from these areas are reported in current literature or abstracts. Only two species in this group seem to have been fairly extensively studied; eels (*Anguilla* spp.) and the carp (*Cyprinus carpio*). The values for eel show this fish to be a good source of B-vitamins. For thiamine in carp the value is put between 0–0·1 μg./g. These results are in agreement with the well-known occurrence of thiaminase in many fresh-water fishes. Thus Deutsch and Hasler (27) found thiaminase in 15 of

TABLE I

B-vitamins in freshwater fishes

Species	*Thiamine* µg./g.	*Riboflavin* µg./g.	*Niacin* µg./g.	*Vitamin B_{12}* µg./g.	*Vitamin B_6* µg./g.	*Pantothenic acid* µg./g.	*References*
ANGUILLIDAE							
Eel *Anguilla* spp.	1·3–2·0 1·5	0·4–4·6 2·0	33–41 35	0·006–0·03 0·01	2·0–3·6 3·0	0·9–2·4 1·5	(13–21)
CATOSTOMIDAE							
Sucker *Catostomis commersonii*	0–0·04 0·05		10–15 12·5				(22, 23)
COREGONIDAE							
Great Lake Whitefish *Coregonus clupiformis*	1·2–1·6 1·5	1·1–1·3 1·2	27–33				(23)
CYPRINIDAE							
Carp *Cyprinus carpio*	0–0·1	0·35–0·45 0·4	10–20 15	0·002		1·0–2·0 1·5	(13, 22–26)
ESOCIDAE							
Pike *Esox lucius*	0·9	0·7	17				(15)
PERCIDAE							
Yellow perch *Perca flavescens*	0·6 ± 0·04	1·7 ± 0·15	17·8 ± 0·8				(22)
Yellow pike *Stizostedion vitrum vitrum*	2·5 ± 0·2	1·6 ± 0·6	23 ± 2				(22)

TABLE II

B-vitamins in salmons, trouts, smelts, etc.

Species	*Thiamine* µg./g.	*Riboflavin* µg./g.	*Niacin* µg./g.	*Vitamin B_{12}* µg./g.	*Vitamin B_6* µg./g.	*Pantothenic acid* µg./g.	*Biotin* µg./g.	*References*
SALMONIDAE								
Atlantic salmon *Salmo salar*	1·4–2·4 2·0	0·6–2·2 1·5	54–88 70	0·04 0·05	6·0–9·8 7·5	20·8 20	0·048	(14–20, 34–38
Chinook salmon *Oncorhyncus tshawytscha*	0·9–1·1 1·0	1·5–2·6 2·0						(30, 31)
Chum salmon *O. keta*	0·8–0·9 1·0	0·6–1·2 1·0						(30–32, 88)
Coho salmon *O. kisutch*	0·8–0·9 1·0	0·9–1·2 1·0						(30, 31)
Pink salmon *O. gorbusha*	1·4–1·5 1·5	0·4–0·7 0·5						(30, 31, 88)
Sockeye salmon *O. nerka*	1·3–1·5 1·5	0·4–0·9 1·0						(30, 31, 33)
Trout *Salmo* spp.	0·6–1·0 1·0	0·5–2·7 1·5	35–56 45	0·05–0·06 0·05	6·9	15·9–23·3 20	0·059	(14–16, 18–20, 30–32, 34–39)
Salvelinus spp.	0·6–1·1 1·0	0·4–1·4 1·0	11–32 25	0·03				(14, 22, 30–32)

TABLE III

B-vitamins in flounder, halibut, etc.

Species	*Thiamine* µg./g.	*Riboflavin* µg./g.	*Niacin* µg./g.	*Vitamin B_{12}* µg./g.	*Vitamin B_6* µg./g.	*Pantothenic acid* µg./g.	*Biotin* µg./g.	*References*
PLEURONECTIDAE								
Atlantic halibut *Hippoglossus hippoglossus*	0·3–1·2 0·7	0·4–1·8 0·8	30–110 60	0·007–0·009 0·008	1·1–5·5 4·0	1·5–3·6 2·5	0·027–0·08 0·05	(11, 14–17, 19, 29–31, 36, 37, 40, 41)
Flounder *Pleuronectes flesus*	0·3–6·6 1·5	1·1–4·6 2·0	20–43 35	0·01	2·1–3·0 2·5	11·0 10	·	(15, 17–20, 38, 41)
Lemon sole *P. microcephalus*	0·9	0·7–0·9 0·8	26–43 35	0·006–0·01 0·008		2·5–4·2 3·0		(38, 42, 89)
Plaice *P. platessa*	0·2–4·6 2·0	0·9–3·3 1·3	21–106 40	0·009–0·011 0·01	1·6–3·1 2·5	6·8–11·2 8·0	0·9	(16–20, 36–38, 41, 43)

31 fresh water species, and none in 9 salt water species. Lieck and Aagren (28) found thiaminase in 10 of 21 fresh water species, and in 1 of 9 salt water species. Although no taxonomic correlation is indicated, the highest concentrations of thiaminase have been found in species of the family Cyprinidae.

In Table II are summarized values for B-vitamins in salmon, trout, smelt, etc. Pacific salmon make up approximately 70 per cent of this group (*Oncorhyncus* spp.). Sautier (30, 31) has investigated this species with regard to thiamine and riboflavin; but these studies seem, unfortunately, to be the only extensive work involving fresh fish. Henderson *et al.* (94) investigated the pyridoxine content of several meat products by the rat bioassay. They reported 5·8 μg. vitamin B_6 per g. fresh salmon. Canned salmon, however, has been more extensively studied (44, 45), and the values reported show that it compared favourably with other protein foods as a source of B-vitamins. The result for Atlantic salmon, as well as for trout, show these species to be good sources of B-vitamins. The values for pantothenic acid and vitamin B_6 may be pointed out.

In Table III are summarized values for flounder, halibut, etc. Relatively few species of this large group have been studied. Atlantic halibut, however, has been extensively investigated, and the average for these species should be reliable estimates. The flatfishes may be classified as fairly good sources of B-vitamins.

In Table IV are summarized values for cod, hake, haddock, etc. The North Atlantic species of this group have been fairly extensively studied. Usually, the gadusfishes are considered as one type with common B-vitamin values. The data summarized in this review generally support such presentation; but it should be pointed out that the saithe (*Gadus virens*) clearly shows higher values for all B-vitamins so far studied in these species. To find out if a relation exists between the size of the fish and the vitamin content, Braekkan (38) analysed the muscle from 19 cod weighing from 0·48 to 7·69 kg. No such relation could be observed, and the standard error of the mean showed very little variation for the B-vitamins studied. The following values were reported: riboflavin 0·85 ± 0·054, niacin 22·8 ± 0·72, pantothenic acid 1·73 ± 0·09, and vitamin B_{12} 0·011 ± 0·00038 μg. per g. In general, the meat from gadus-fishes is a fairly good source of B-vitamins.

In Table V are summarized data for B-vitamins in herrings, sardines, anchovies, etc. Only a few species have been examined, and only herring (*Clupea harengus*) has been extensively studied by several investigators. Again the values for thiamine show great variation, and in some cases very low values. These results may be seen in relation to the findings of thiaminase in these species by Lieck and Aagren (28). Generally the species in this group are a good source of B-vitamins.

In Table VI are summarized data for B-vitamins in tuna, bonito, mackerel, etc. Common mackerel (*Scomber scombrus*) has been investigated by several groups, and the values show this fish to be a very good source of B-vitamins. It may be noted that all species tabulated take into consideration the great relative variation of vitamin B_{12} values. In the author's opinion, this is more a result of analytical differences than of such great differences between the species. When investigations of vitamin B_{12} are reported, more details should be given with regard to the extraction method used, to make a proper judgment of the results possible. In general, mackerel yield large quantities of B-vitamins, and the values for niacin are especially high compared with other protein foods.

In Table VII are reported values for mullet, jack, seabass, etc. This is by far the largest group in the FAO-statistics (4), but relatively few data are reported in the literature of B-vitamin studies. As might be expected from the composition of this group, the B-vitamin values show considerable variation. It is of interest to note the

TABLE IV

B-vitamins in cod, hakes, haddocks, etc.

Species	*Thiamine* μg./g.	*Riboflavin* μg./g.	*Niacin* μg./g.	*Vitamin B_{12}* μg./g.	*Vitamin B_6* μg./g.	*Pantothenic acid* μg./g.	*Biotin* μg./g.	*References*
GADIDAE								
Cod (Atlantic) *Gadus callarias*	0·5–1·8 0·7	0·2–1·6 0·8	15–23 20	0·002–0·011 0·01	1·2–2·8 1·7	0·8–3·1 1·7	0·026	(14–20, 25–30, 32, 33, 36, 37, 43, 44, 52)
Cod (Pacific) *Gadus macrocephalus*	0·9	1·4–1·7 1·5		0·0009		1·0–1·8 1·5		(21, 30, 32)
Cusk *Brosme brosme*		1·0–2·0 1·5	27–28 30	0·011–0·012 0·01	2·88	3·0–3·1 3·0	0·045	(16, 29, 36–38, 41, 49)
Haddock *Gadus aeglefinus*	0·3–1·0 0·7	0·2–1·6 1·0	31–44 40	0·005–0·02 0·015	1·22	0·4–2·9 2·5	0·048	(14, 29, 33, 36–38, 41, 49, 52)
Ling *Molva molva*		0·6–1·0 0·8	21–25 25	0·004–0·008 0·006	2·6	2·4–3·6 3·0	0·042	(16, 36–38, 49)
Pollack *Gadus pollachius*		0·9–1·3 1·0	16–20 20	0·008–0·022 0·01	1·23	2·5–4·2 3·0	0·032	(16, 36–38, 49)
Saithe *Gadus virens*	1·0	1·7–3·0 2·0	32–44 35	0·022–0·05 0·035	4·73	3·5–4·1 4·0	0·072	(16, 36–38, 49, 51)

TABLE V

B-vitamins in herrings, sardines, anchovies, etc.

Species	*Thiamine* µg./g.	*Riboflavin* µg./g.	*Niacin* µg./g.	*Vitamin B_{12}* µg./g.	*Vitamin B_6* µg./g.	*Pantothenic acid* µg./g.	*Biotin* µg./g.	*References*
CLUPEIDAE								
Anchovy *Engraulis* spp.	0·05–0·07	1·1–1·3 1·2		0·0033	1·75			(17–19, 32)
Brisling, sprat *Clupea sprattus*	0·4	2·6	48	0·11		10·9		(16)
Herring (Atlantic) *Clupea harengus*	0·08–1·3 (0·4)	0·9–3·3 3·0	20–63 40	0·08–0·14 0·1	3·5–5·2 4·5	9·3–9·7 10	0·09–0·16 0·1	(14–20, 25, 35–37, 41, 43, 53–55)
Herring (Pacific) *Clupea pallassii*	0·11–0·40 (0·3)	1·8–2·7 2·2		0·005–0·024				(30–32)
Pilchard *Sardinops caerulea*	0·07	3·0	74	0·17	2·4–3·0	4·9–8·3	0·19–0·34	(44, 56)

TABLE VI

B-vitamins in tunas, bonitos, mackerels, etc.

Species	*Thiamine* µg./g.	*Riboflavin* µg./g.	*Niacin* µg./g.	*Vitamin B_{12}* µg./g.	*Vitamin B_6* µg./g.	*Pantothenic acid* µg./g.	*Biotin* µg./g.	*References*
SCOMBRIDAE								
Albacore *Germo alalunga*	0·4–0·7 0·5	1·1	11–14	0·0017	4·4	4·2	0·03	(15, 32, 44)
Bigeye tuna *Parathunnus obesus*	0·6	0·6	143	0·005				(57)
Bluefin tuna *Thunnus thynnus*	1·4–2·3 2·0	0·8–2·2 1·2	62–108 85	0·032–0·066 0·04	3·7–10·0 4·5	3·8–7·0 5·0	0·02–0·06 0·05	(11, 13, 15, 17, 19, 20, 44, 48)
Frigate *Auxis thazard*				0·004–0·012 0·01	4·7–5·7 5·0			(13, 58, 59)
Hairtail (cutlass fish) *Trichiurus* spp.	0·7	6·6		0·0006				(32, 64, 65)
Mackerel (Atlantic) *Scomber scombrus*	0·2–2·0 1·0	1·6–6·6 3·5	41–114 75	0·02–0·13 0·1	5·0–8·9 7·5	9·7–10·9 10	0·06–0·08 0·07	(11, 14, 16, 20, 29, 33, 36–39, 41, 43, 50, 51, 55)
Mackerel (Pacific) *Scomber japonicus*				0·009–0·015	4·6–5·4 5·0	1·6–3·2		(13, 57, 59, 60)
Skipjack *Katsuvonus* spp.	0·60	0·40	72	0·0025–0·006				(13, 57, 61)
XIPHIIDAE								
Broadbill swordfish *Xiphias gladius*	0·53	0·49–0·50	74–91	0·0057		0·5	0·012	(29, 62)

very low values for niacin in some species, e.g. for *Mugil* spp. reported values are from 7·7 to 69 µg. per g. In general, the species so far studied in this group may be classified as fairly good sources of B-vitamins.

In Table VIII are summarized data for B-vitamins in shark, ray, etc. Very few species have been studied, but fortunately fairly extensive data are available for species from four different families. Generally, they may be classified as good sources of B-vitamins. It is interesting to note that the closely related species porbeagle and mako show fairly equal values, although they live in different waters.

Finally in Table IX are summarized data for B-vitamins in crustacean and molluscs. The values for crustaceans refer to investigations of the muscle. Without discussing the result in detail, these shellfish may be classified as only moderate sources of B-vitamins. Usually, the crabs in Europe are canned with the viscera, and this product is a very good source of B-vitamins. Shaikmahud and Magar (96) have investigated five species of Bombay prawns (*Penaeus penicilatus*, *Metapenaeus affinis*, *Parapenaeus stylifera*, *Hippolysmata ensirostris* and *Leander tenuipes*). They report values within the following limits: thiamine 0·07–0·14, riboflavin 1·6–2·0, and niacin 21–48 µg. per g.

The molluscs have been fairly extensively studied only in the United States. Clams may be pointed out as a very rich source of vitamin B_{12}. Proctor and Lang (95) found fresh samples of soft shell clams (*Mya arenaria*) and hard shell clams or quahaugs (*Venus mercenaria*) to contain 6·0–9·7 µg. vitamin B_{12} per g. dry weight, or up to three times more than animal liver assayed simultaneously. The visceral mass was found to contain the highest concentration. Clams, however, show very high contents of thiaminase (74, 76). Oysters have mainly been studied by

TABLE VII

Mullets, jacks, sea-basses, etc.

Species	*Thiamine* µg./g.	*Riboflavin* µg./g.	*Niacin* µg./g.	*Vitamin B_{12}* µg./g.	*Vitamin B_6* µg./g.	*Pantothenic acid* µg./g.	*Biotin* µg./g.	*References*
BLENNIDAE								
Wolf fish *Anarrhichas lupus*	0·7	0·7–0·9 0·8	13–25 20	0·018–0·028 0·02	3·42 3·5	5·0–6·4 5·0	0·037	(16, 36–39)
CARANGIDAE								
Horse mackerel *Trauchurus trauchurus*	1·8	1·4	52	0·127	2·7–3·6	2·0–5·0		(21, 57, 59)
Yellowtails and Amberjacks *Seriola* spp.	1·0	0·4	68	0·013	1·3–1·9	4·6–7·9		(21, 57, 59)
LUTIANIDAE								
Red snapper *Tutianus blackfordii*	0·7–1·7 1·0	0·48	7–18 15					(33, 34)
OPHIODONTIDAE								
Lingcod *Ophidon elongatus*	0·5	0·4		0·18				(30, 31, 66)
MUGILIDAE								
Mullett *Mugil* spp.	0·55	0·98	7·7–6·9	0·0006–0·0025	4·2–4·3	6·9–8·3		(13, 21, 31–33, 59, 63–65, 67)
MURAENIDAE								
Sharp-toothed eel *Muraenesox tababonoides*	0·3	1·9	10					(64)
SCIAENIDAE								
Drums, Maigre *Sciaena* spp.	0·2	5·3	6–16					(64, 65)
SCORPAENIDAE								
Red-fish (Ocean perch) *Sebastus marinus*		0·7–1·1	20	0·01	2·3	3·6	0·01	(16, 25, 36–38)
Rockfishes *Sebastodes* spp.	0·8	1·1–1·5	8	0·12		0–1·5		(30–32, 61, 66)
SERRANIDAE								
Black sea bass *Stereolepis gigas*	1·0	0·5	24					(63)
Grouper *Epinephelus morio*	1·1	3·7	14					(63)
Rock bass *Paralabrax clathratus*	0·5	0·5	10					(63)
SPARIDAE								
Pork fish *Anisotrmus interruptus*	0·6	0·5	54					(63)
Red sea bream *Chrysophrys major*	0·3	2·5	19					(63)
STROMATIDAE								
Pompanos *Palometa media*	1·1	0·9	30					(63)

TABLE VIII

B-vitamins in sharks, rays, etc.

Species	*Thiamine* µg./g.	*Riboflavin* µg./g.	*Niacin* µg./g.	*Vitamin B_{12}* µg./g.	*Pantothenic acid* µg./g.	*References*
CARCHARIIDAE						
Dogfishes *Mustelus* spp.	0·26	0·27	56	0·005		(57)
LAMNIDAE						
Porbeagle *Lamna cornubica*	0·8	0·9–2·8 1·5	70–100 75	0·025–0·026 0·025	2·5–3·3 3·0	(38, 42)
Mako *Isurus oxyrrhynchus*		0·95	99	0·012	2·5	(42)
RAJIDAE						
Rays and skates *Raja* spp.	0·2–0·3 0·25	3·7–4·1 4·0	23–24 25	0·008–0·01 0·01	4·6–12·3 7·5	(33, 42)
SPINACIDAE						
Spiny dogfishes *Squalus acantias*	0·5	1·0–1·8 1·5	51–53 50	0·011–0·026 0·015	5·7–8·0 7·5	(16, 33, 42)

TABLE IX

B-vitamins in crustaceans and molluscs

Species	*Thiamine* μg./g.	*Riboflavin* μg./g.	*Niacin* μg./g.	*Vitamin B_{12}* μg./g.	*Vitamin B_6* μg./g.	*Pantothenic acid* μg./g.	*Biotin* μg./g.	*References*
CRUSTACEA								
Crabs *Cancer* spp.		0·9	17–28	0·13	2·3	7·1	0·098	(19, 36, 37, 42)
Crayfish *Neophrops norvegicus*		0·6	24	0·027	2·1	4·1	0·038	(16, 36, 37)
Deep sea prawns *Pandaluss borealis*	0·4–0·8 0·5	0·3–0·7 0·5	11–40 20	0·046	1·0–1·5 1·2	2·3	0·031	(16–20, 30, 31, 36, 37)
Lobster *Homaris* spp.	0·8–0·9	0·4–0·6	12–21	0·005				(18–20, 29)
Shrimps *Penaeus* spp.	0·1–0·5 0·2	0·1–0·7 0·25	11–53 25	0·009	0·8–0·57 0·25	1·2–3·8 2·5		(29, 68, 93)
MOLLUSCA								
Clams *Var.* spp.	0·4–1·4	0·9–2·9 1·8	13	0·13–0·62				(29–31, 69, 90)
Octopus *Octopus bimaculatus*	0·02–0·48 0·25	0·4			3·6		0·054	(30, 31, 36, 37)
Oysters *Ostrea* spp. *Crassostrea* spp.	0·7–2·9 1·2	0·6–3·5 1·8	13·6–38·8 20	0·15–0·46 2·0	1·1–3·2	1·4–5·3	0·087	(30, 40, 69–72)
Scallops *Pecten* spp.		0·65	12	0·013				(29)

Fieger (71) and by Wentworth and Harvey (72). Considerable variation was found, according to the time of the year, age, size and location of the catch. Some loss of the B-vitamin seemed to take place during freeze-storage, mainly for thiamine and vitamin B_6, while niacin showed no detectable loss. The values for vitamin B_{12} are high, and result probably from vitamin B_{12} producing bacteria in the sea or in the digestive tract. It may be pointed out that oysters contain no, or very little, thiaminase (74, 77).

This survey of data at present available for the B-vitamin contents of fish shows that this important food has been fairly extensively studied in recent years. More data are reported for vitamin B_6, vitamin B_{12} and biotin, making it possible to evaluate fish as a source of these B-factors. A few values for inositol are also reported (46, 78, 79), but more values are necessary to judge the appearance of this factor. If the different fish are grouped according to their fat content, as is common in food composition tables, the recent studies support the general claim that fat and medium fat fishes contain more B-vitamins than meagre fishes. If the different vitamins reviewed in the present paper are considered separately, the following general conclusion may be drawn:

Thiamine generally occurs in the same concentration in fish as in beef and veal meat, but clearly less than in pork, mutton and lamb. The presence of thiaminase in some species has to be considered. In animal feeding, great destruction of thiamine added to the food has been observed when raw fish is fed to fur-bearing animals (80, 81). Melnick *et al.* (82) have carried out human availability studies, which indicated the destruction of thiamine in the gastro-intestinal tract following concomitant ingestion of raw clams. Of fish products for direct human consumption, salted and marinated herring also contained thiaminase. They found smoked carp to give theoretical recovery of thiamine, and assumed that smoke-processing destroys the thiaminase. This point needs further confirmation in studies with more samples and species. Because fish products are often consumed raw or in partially cooked state in many areas of the world, thiaminase should be considered if malnutrition is observed. Riboflavin shows varying values, but as a rule fish contain less than meat. This variation is expressed in most comparative studies; thus Leong (92) found values for riboflavin in Malayan fish and fish products ranging from 0·7 to 7·1 μg. per g. Some fat fish, however (among them the nutritionally important species, herring (*Clupea* spp.) and mackerel (*Scomber* spp.)), showed fairly high values for this vitamin.

Niacin is usually considered to be present in fish in small amounts, with the exception of salmon, mackerel and tuna (1). The data now available show that this view needs revision. Meagre fishes, as most fresh-water species, gadus-fishes and most mullet, jack, seabass, etc., and also shellfish, contain relatively small amounts. Values between 20 and 35 μg. per g. are most usual. For most other species the values are higher; thus flat-fish show values between 20 and 110 μg. per g., with most likely averages of 35 to 60 μg. per g. Similarly, shark showed values from 23 to 100 μg. per g. with most averaging above 50 μg. per g. These species may be claimed equal to beef meat as a source of niacin. The fat fish, such as tuna, bonito, mackerel, herring and salmon, showed average values as high as or higher than those accepted for veal. These fish are very important and rich sources of niacin. The generally high niacin content in fish seems reflected in the different products.

Giacomi (91) thus found fish paste to contain 10 μg. niacin per g. compared with 5 μg. per g. in meat paste.

Vitamin B_{12} is not usually reported in food composition tables for nutritional use, as the requirement for this vitamin is not known. Generally fish is a good source; the fat fish and even the molluscs are particularly rich sources of this vitamin.

Vitamin B_6 has only in recent years been more extensively studied in fish and fish products (17, 36, 46). Although some variations are found, generally fish is a very good source of this important vitamin. Canning seems to cause a reduction in the content; but none the less canned fish products are very good sources of vitamin B_6 (36).

Pantothenic acid is universally distributed in all living cells, and this is probably the reason for the rare occurrence of pantothenic acid deficiency in humans. It is thus difficult to evaluate the importance of this vitamin, and only quantitative considerations can be made. Generally, fish contains less pantothenic acid than most common meats, but exceptions may be pointed out. Thus Atlantic salmon (*Salmo salar*) and trout (*Salmo* spp.) were found to be fairly rich sources. The variations observed in fish may be a result of the dietary level of pantothenic acid, as observed for tissues of birds and mammalians (83, 84). Pearson and Darnell (85) have reported a 33 per cent loss of pantothenic acid in the drip from defrosting frozen meat. This finding emphasizes the importance of direct cooking of frozen fish as usually recommended. Not only will the flavour remain, but the loss of B-vitamins from the broken cells may be avoided. Biotin is present in most food products. Only limited results are as yet available from studies of fish and shellfish. If the data for fish products (37) are compared with those reported for meat and meat products (85) and generally for different foods (87), fish and fish products may be considered very good sources of biotin.

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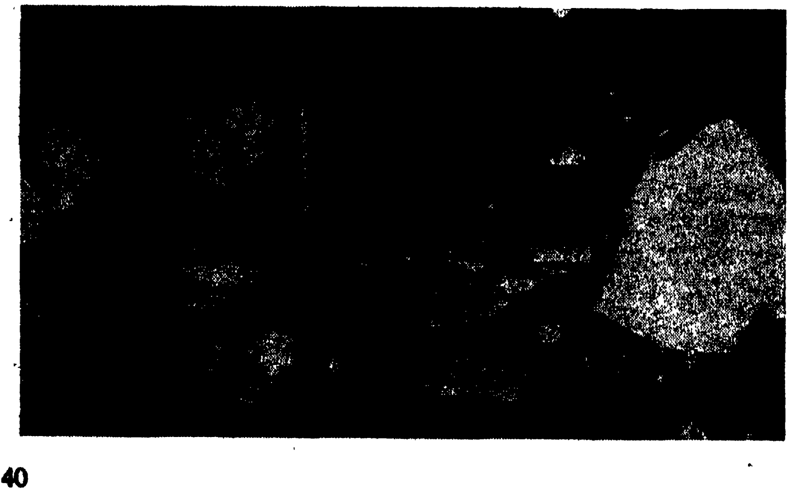

Shrimp and shellfish are particularly rich in vitamins and command an increasing world trade, particularly from tropical and semi-tropical waters. Grounds rich in shrimp have been found and developed off the coast of Cochin, India, and here girls in one of the processing plants are packing shrimp for treatment in deep freeze prior to export to U.S.A. *Photo: F. L. Cyprien.*

B-VITAMINS IN SOME FISH PRODUCTS

by

OLAF R. BRAEKKAN

B-vitamins in some fish products are here reviewed, and summarized values are given for the B-vitamines thiamine, riboflavin, niacin, vitamin B_{12}, vitamin B_6, pantothenic acid and biotine.

Weight-by-weight cured fish products usually show higher values than the corresponding fillets. Canned products usually show weight-by-weight values of the same order as for the corresponding fresh fish.

Smoked and canned products of herring, mackerel, tuna and salmon are found fairly good sources of B-vitamins. They usually contain high amounts of niacin, in some cases much higher than common meat products.

Canned shellfish show generally low values for the B-vitamins; but products which include the viscera are good sources of vitamin B_{12}. Molluscs generally contain very high concentrations of vitamin B_{12}.

Canned products of cod liver and roe and of herring roe are judged good dietary sources of B-vitamins.

In general, fish products compare favourably with other major protein foods as sources of B-vitamins.

LES VITAMINES B DANS QUELQUES PRODUITS DU POISSON

On a considéré les vitamines B dans quelques produits du poisson. On a donné les valeurs résumées pour les vitamines B: thiamine, riboflavine, niacine, vitamine B_{12}, vitamine B_6, acide pantothénique et biotine.

En égalité de poids, les produits traités du poisson montrent habituellement des valeurs plus hautes que les filets correspondants. En égalité de poids, les produits en boîtes montrent habituellement des valeurs comparables à celles des poissons frais correspondants.

Les produits, fumés et en boîtes, de hareng, maquereau, thon et saumon sont apparus comme des sources assez bonnes de vitamines B. Ils contiennent habituellement des montants élevés de niacine, en quelques cas supérieurs à ceux des produits courants de la viande.

Les coquillages et crustacés montrent en général des faibles teneurs en vitamines B, mais les produits qui comportent les viscères sont de bonnes sources de vitamine B_{12}. Les mollusques contiennent en général de très hautes concentrations en vitamine B_{12}.

On estime que les produits en boîtes de foie et de rogue de morue et de rogue de hareng sont de bonnes sources diététiques de vitamines B.

D'une façon générale, les produits de poisson se comparent d'une façon favorable avec les autres aliments protéiques principaux comme sources de vitamines B.

LAS VITAMINAS B EN ALGUNOS PRODUCTOS PESQUEROS

Se han hecho análisis de las vitaminas del grupo B en algunos productos pesqueros. Se dan los valores para las vitaminas B tiamina, riboflavina, niacina, vitamina B_{12}, vitamina B_6, ácido pantoténico y biotina.

Generalmente, a igualdad de peso, los productos pesqueros curados tienen índices mayores que los filetes correspondientes, y el pescado en conserva valores análogos al pescado fresco correspondiente.

Los productos de arenque, caballa, atún y salmón, ahumados o enlatados, son fuentes bastante buenas de las vitaminas B, y generalmente contienen cantidades elevadas de niacina, y en algunos casos cantidades muy superiores a las de los productos de carne.

En general, las conservas de mariscos contienen pocas vitaminas B, pero los productos que incluyen las vísceras son buenas fuentes de vitamina B_{12}. Los moluscos en general contienen concentraciones muy elevadas de vitamina B_{12}. Las conservas de hígado y huevas de bacalao y de huevas de arenque son buenas fuentes de vitaminas B_{12}.

En general, los productos pesqueros contienen tantas vitaminas B_{12} como otros alimentos proteicos.

IN my previous paper, the B-vitamin contents of fresh meat of fish and shellfish are reviewed. The world grand total of fish landed is, however, only partly consumed fresh or frozen. Thus, according to the *FAO Yearbook of Fishery Statistics* (2), the disposition of the catch shows generally the following percentages: marketing fresh 43, freezing 8, curing 24, canning 9, reduction to meal and oil 13, and miscellaneous purposes 3. The present paper intends to cover cured and canned fish products.

The literature on B-vitamins in fish products is, however, relatively limited. The first extensive survey was given by Lunde (3), who gave tables from vitamin studies in canned products, including canned fish products. Kühnau (4) also reported some canned products in his table on vitamins in fish. With few exceptions (5, 6), most values for B-vitamins in fish products are reported in comparative studies of different foods, and the fish products are generally reported without specifications as to kind of fish and species within the family. Thus, proper comparison and evaluation of the results from different countries are often difficult or impossible to obtain. The author has found it necessary to limit the present review mainly to results from studies carried out in Europe and America.

In the previous review (1), the analytical problems related to the estimation of B-vitamins in fish were discussed. For canned products additional difficulties enter into the picture. Thus, additives in the form of other nutrients of vegetable origin and different spices introduced to give flavour to the food, may contain substances which interfere with the analysis.

A method which gives good results for one product may not be satisfactory for other products. Thus, many fish products are canned in oil. Such fatty material may cause disturbances in the microbiological assays, especi-

TABLE I

B-vitamins in some fish products produced by curing of fish

Product	*Thiamine* μg./g.	*Riboflavin* μg./g.	*Niacin* μg./g.	*Vitamin* B_{12} μg./g.	*Vitamin* B_6 μg./g.	*Pantothenic acid* μg./g.	*Biotin* μg./g.	*References*
Stockfish	0·08	2·0–2·6 2·4	57–160 75	0·05–0·12 0·10	2·5–3·70 3·0	16·7–21·2 17·5	0·12–0·18 0·16	(6–8, 14, 37, 36, 42)
Klipp-fish	0·26–1·29 0·08	0·7–2·7 2·0	16–28 25	0·035	1·6–3·1 2·0	2·6–3·6 3·4	0·05–0·08 0·065	(6–12, 14, 42)
Lute-fish		0·05	2·3	0·012	0·7	0·8	0·025	(6–8)
Smoked fish								
Cod		0·15–1·1 0·5	13–35 25	0·002–0·027 0·015	2·2	1·3–3·4 2·0	0·014	(13, 14)
Haddock	0·45–1·0 0·5	0·1–0·4 0·25	35–52 40	0·008–0·020 0·012		0·7–1·9 1·2		(13)
Herring	0·07–0·82 0·4	1·6–2·8 2·0	39–58 50	0·15	2·0–4·8 3·5	8·8	0·105	(6–11)
Mackerel	1·0–2·0 1·4	2·2–4·7 3·5	59–130 90	0·12	3·4–6·8 5·0	5·2	0·077	(6–12)
Halibut	0·6	0·4–1·7 1·0	15	0·006	0·3–0·8 0·5	7·2	0·025	(6–11)
Salmon	1·1–4·5 2·0	0·7–1·9 1·0	50–108 75	0·07	3·4–8·7 6·4	7·1	0·063	(6–12)
Eel	0·7–1·8 1·4	2·2–4·8 3·0	28–57 40		1·3–2·0 1·5			(9–12)
Salted herring	0·24–0·40 0·3	1·6–3·6 2·0	20–34 25	0·08	1·6–3·2 2·1	5·0	0·09	(6–12)

TABLE II

B-vitamins in canned sardines, brisling and herring

Product	*Thiamine* μg./g.	*Riboflavin* μg./g.	*Niacin* μg./g.	*Vitamin* B_{12} μg./g.	*Vitamin* B_6 μg./g.	*Pantothenic acid* μg./g.	*Biotin* μg./g.	*References*
Sardines *Clupea pilchardus*	0·5–0·6	1·0–1·2	43–52					(15)
Pacific sardines *Sardinops caerulea*								
natural	0·00–0·42 0·2	0·9–3·7 3·0	62–88 74		2·4–3·0 2·8	1·2–6·5 4·5	0·19–0·34 0·24	(5, 24–26)
in tomato sauce	0·06–0·17 0·1	1·2–3·8 3·0	54–64 58		1·9–2·5 2·2	4·9–8·3 6·0	0·20–0·35 0·27	(5, 24–26)
Brisling sardines *Clupea sprattus*								
in oil	0·1–2·6 0·3	1·4–6·2 3·3	25–67 60	0·08–0·11 0·10	1·5–2·6 2·5	6·0–9·1 8·0	0·14–0·16 0·15	(6, 10–12, 16–18)
in tomato sauce	0·2–0·45 0·3	1·4–3·9 3·3	50–68 55	0·09–0·12 0·10	1·2–2·6 2·2	5·0–6·8 6·0	0·14–0·18 0·15	(7–11)
Herring sardines *Clupea harengus*								
in oil	0·03–0·60 0·4	1·6–4·1 3·0	19–57 50	0·08–0·10 0·10	1·0–2·0 1·5	4·2–9·5 7·5	0·08–0·13 0·11	(5–8, 16, 18)
in tomato sauce	0·3–0·45 0·4	2·9–3·0 3·0	41–58 50	0·09–0·11 0·10	1·3–1·5 1·4	7·0–7·3 7·0	0·07–0·13 0·11	(6–8, 14)
Fresh herring[1] in bouillon		2·4	32	0·11	1·3–1·9 1·5	7·7	0·11–0·12 0·11	(6–8)
Fresh herring[1] in tomato sauce		2·9	38	0·09	1·6–1·9 1·7	7·5	0·19–0·11 0·10	(6–8)
Marinated herring[1]		2·5	47	0·10	2·3	8·2	0·09	(6–8)
Kippered herring		2·0–4·7 3·5	28–38 50	0·015	2·5	10·4	0·12	(6–8, 16, 18)

[1] Average sample of 3–5 different brands.

TABLE III

, tunas and salmons

Product	*Thiamine* µg./g.	*Riboflavin* µg./g.	*Niacin* µg./g.	*Vitamin B_{12}* µg./g.	*Vitamin B_6* µg./g.	*Pantothenic acid* µg./g.	*Biotin* µg./g.	*References*
Pacific mackerel *Pneumatophorus* and *Trauchurus*	0·18–0·33 0·25	2·9–3·8 3·3	80–94 87		2·5–2·9 2·7	4·3–5·4 4·7	0·12–0·23 0·18	(5)
Atlantic mackerel *Scomber scombrus* in oil	0·40–0·86 0·58	1·7–2·6 2·0	50–60 58		1·8–2·6 2·1	2·4–4·0 3·1	0·03–0·04 0·03	(5)
Small mackerel[1]								
in oil	1·0	3·5	55–80	0·08	1·7–3·9	5·5	0·10–0·17	(6–8, 14, 18)
in tomato sauce	1·0	3·2	88	0·05	2·0–3·1	5·9	0·10–0·12	(6–8)
in bouillon	1·0	2·9	100	0·05		5·7		(6)
marinated	1·0	4·0	83	0·09	4·3	5·6	0·10	(6–8)
Mackerel fillets in oil	0·6	1·6–4·7 3·5	106	0·10	2·3–4·1 2·7	6·9	0·08–0·12 0·10	(6, 9, 11)
Pacific tuna[2] in bouillon	0·40–0·66 0·53	0·9–1·5 1·1	102–155 135		3·7–5·2 4·4	3·5–5·6 4·2	0·03–0·06 0·03	(5)
Atlantic tuna *Thunnus thynnus*								
in oil	0·2–0·7 0·5	0·5–1·4 1·0	90	0·03	2·0–4·4 3·5	3·1	0·02	(6–11)
in bouillon		1·0–1·1 1·0	98–141 120	0·02–0·03 0·03	4·7	2·3	0·02	(6–8, 19)
Salmon *Oncorhyncus* spp.								
in bouillon	0·14–0·52	1·1–2·0	62–89 75		3·9–5·0 4·5	4·7–7·3 5·8	0·11–0·19 0·15	(5, 25, 26)

[1] Average sample of at least three different brands.

[2] Species: *Germo*, *Neothunnus*, *Thunnus*, and *Katsuwonus*.

TABLE IV

B-vitamins in canned shellfish and miscellaneous products

Product	*Thiamine* µg./g.	*Riboflavin* µg./g.	*Niacin* µg./g.	*Vitamin B_{12}* µg./g.	*Vitamin B_6* µg./g.	*Pantothenic acid* µg./g.	*Biotin* µg./g.	*References*
Shellfish								
Crab natural	0·01–0·5 0·4	1·4–4·0 2·5	17–25 20	0·14	2·0–3·6 2·5	7·1	0·09	(6–8, 26)
Crab paste	0·6	1·9	12	0·44	1·3	15·7	0·12	(6–8)
Shrimps	0·01–0·6 0·3	0·4–3·7 2·5	7–34 15	0·03	0·1–3·7 0·2	1·7–3·5 2·5	0·02	(6–8, 24–26)
Molluscs								
Clams	0·02–0·21 0·1	0·52–1·68 0·93	3–20 9·5		0·3–1·33 0·83			(26)
Oysters	0·12–0·33 0·20	1·25–3·30 2·0	5·6–16·5 10		0·1–0·9 0·4			(26)
Miscellaneous								
Cod liver natural		3·4	15	0·10	1·7	4·3	0·91	(6–8)
Cod liver paste	0·8	4·3	12	0·10	0·7	12·9	0·40	(6–8)
Cod roe-liver paste	1·3	4·4	12	0·13	1·2	12·0	0·34	(6–8, 16, 20)
Cod roe	2·5	5·5	8	0·15	1·4	19·7	0·17	(6–8, 20)
Cod roe caviar	3·3	4·6	5	0·09	1·4	19·4	0·09	(6–8, 20)
Herring soft roe	0·4	7·5	24	0·10		15·5	0·05	(6–8, 16)
Herring hard roe		3·2	14	0·11	1·5	17·3	0·22	(6–8)
Fish balls in bouillon	0·1–0·7 0·5	0·9–1·2 1·0	14–14 14	0·005–0·006 0·005	0·6–1·0 0·8	1·7–1·9 1·8	0·014	(6–11)
Fried fish cakes	1·0	1·0	11	0·01	0·5	2·5	0·015	(6–8, 20)

Values of the same order obtained for fried fish cakes in gravy and in bouillon.

ally with *Lactobacillus casei*, which usually is employed for the estimation of riboflavin.

Neilands *et al.* (5) found fluctuation in the values for biotin in canned fish, which they assumed at least partially to be caused by the fatty acids of the samples.

The most common method of curing is salting of filleted or whole fish. Unfortunately, few proper values are reported for such products, with the possible exception of salted herring ("spekesild"). The author has included this product in the tables, but found it possible only to give general considerations for salted fish. In some cases the curing is light, and salt is only sprayed on the fish or the fillets to make them keep a couple of days. In this case, the loss through liquid drawn out of the fish is not substantial. In other cases heavy salting is carried out, often with changes from one brine to another. In this case considerable losses may be induced. Thus, salted herring has only about 50 per cent of the B-vitamin content of fresh herring (6–12).

In Table I are summarized the B-vitamin values for some important cured fish products. Stockfish may be produced from cod, haddock or saithe, and will naturally reflect the normal vitamin values for fresh fish. Thus, stockfish from haddock shows the highest values for niacin, and stockfish from saithe shows the highest values for vitamin B_{12} (14). In klippfish, the curing with salt before drying has "extracted" much of the B-vitamin of the raw material, but the drying results in a concentration to make klippfish weight-by-weight richer in B-vitamins than fresh cod. For the smoked fishes it may be noted that they generally, weight-by-weight, show values equal to those of the corresponding fresh fillets (1). Smoked herring, mackerel and salmon are rich in niacin and vitamin B_6.

In Table II are summarized values for canned sardine, brisling and herring. It may be pointed out that corresponding products of Pacific sardine (*Sardinops caerulea*), brisling (*Clupea sprattus*) and herring (*Clupea harengus*) show B-vitamin values of the same order of magnitude. The values for niacin and biotin may be considered as fairly rich. The vitamin B_6 values are somewhat lower than for corresponding fresh fish, but still justify the term "rich".

The very low limits reported for thiamine in some products probably reflects the thiaminase in these species.

In Table III are summarized B-vitamin values for mackerel, tuna and salmon. All the quoted products are very rich in niacin, especially tuna, with values up to 155 μg. per g., which is much higher than for meat of animal origin. They are also rich in vitamin B_6. While mackerel and salmon are rich in biotin, tuna products show relatively moderate values for this vitamin.

Guerrant *et al.* (23) report the following values for salmon paste, as a result of collaborative studies: thiamine 0·1, riboflavin 3·0, pantothenic acid 6·4, and niacin 61 μg. per g.

In Table IV are summarized values for canned shellfish and miscellaneous canned fish products. Except for the high content of vitamin B_{12} in crab paste, these products show very moderate B-vitamin content. Teeri *et al.* (19) reported the following values for canned crab: riboflavin 0·8, niacin 13·7, and vitamin B_{12} 0·005 μg. per g. The very low vitamin B_{12} content (as compared with natural crab and crab paste in the table, with respectively 0·14 and 0·44 μg. vitamin B_{12}/g.) reflects differences between products with only claw meat and those which contain the whole crab, including viscera. Fellers and Harris (21) found 2·3 μg. thiamine and 1·5 μg. riboflavin per g. in canned Atlantic blue crab. Canned lobster is little investigated. Hjarde (10) reports 0·4–0·6 μg. thiamine per g., and Hjarde and Lieck (11) 0·1–0·3 μg. riboflavin per g.

Canned "cod liver natural", "liver paste", "roe liver paste" and "roe" are products rich in B-vitamins. The values for vitamin B_{12} and biotin are especially high. The important fish products: "fish balls in bouillon" and "fried fish cakes" show moderate values. The latter product is canned either in gravy or in bouillon, but the vitamin values are practically the same (14).

Canned molluscs have been omitted from these tables, since few values are available. Chatfield (22) gives the following general values: thiamine 1·2, riboflavin 1·1, and niacin 9 μg. per g. of canned molluscs.

Proctor and Lang (28) investigated the vitamin B_{12} content of fresh and canned clams. They found commercially-canned whole clams to contain 3·8 μg. vitamin B_{12} per g. dry weight, or about half the value for fresh clams. They assumed that there had been a loss in the processing, or that the results reflected differences in species or locality of collection. Braekkan (14) found canned common mussel to contain 0·17 μg. vitamin B_{12} per g. net weight. It may be concluded that cured and canned fish products generally can be favourably compared with other major protein foods as a source of B-vitamins. Fluctuation of the different values with species and type of product are frequently encountered.

Summary

A review has been made of B-vitamins in some fish products. Summarized values have been given for the B-vitamins: thiamine, riboflavin, niacin, vitamin B_{12}, vitamin B_6, pantothenic acid and biotin.

The cured products, stockfish and klippfish and different smoked fish, showed weight-by-weight higher values than corresponding fresh fillets. Smoked herring, mackerel and salmon were especially rich in niacin and vitamin B_6.

Canned fish, sardine, brisling and herring showed fairly equal values and weight-by-weight of the same order as for the corresponding fresh fish.

Canned mackerel, tuna and salmon were found fairly good sources of B-vitamins. They contained especially high amounts of niacin, some parts much higher than common meat products. Also the values for vitamin B_6 were fairly high.

Canned shellfish generally showed low vitamin values,

but products which included the viscera were good sources of vitamin B_{12}. Molluscs were generally very good sources of vitamin B_{12}.

Canned products of cod liver and roe and of herring roe were good B-vitamin sources.

Generally fish products compared favourably with other major protein foods as sources of B-vitamins.

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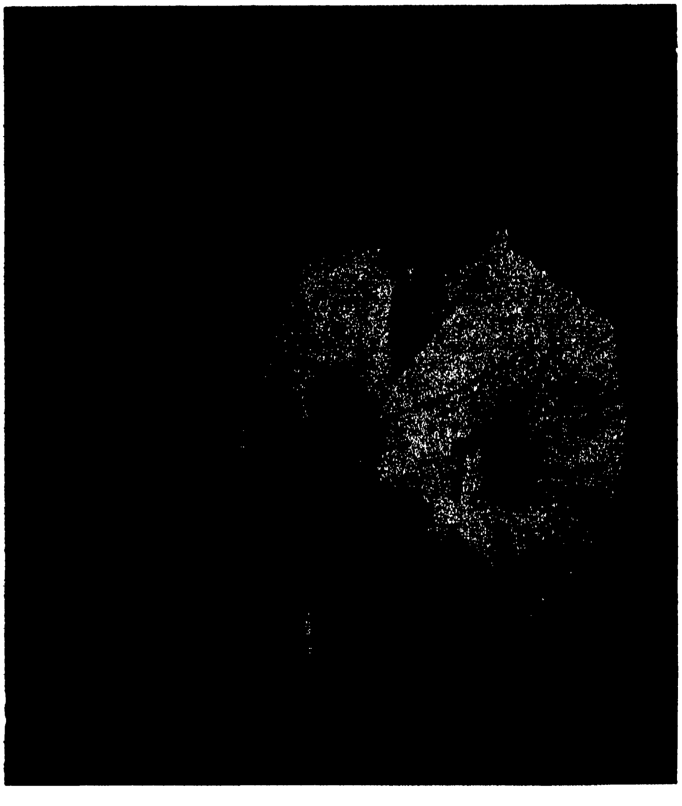

Unceasing and persistent scientific research is conducted by chemists in many institutions all over the world to discover all that can possibly be known about the various constituents of fish. Here, one research chemist—it happens to be Dr. H. L. A. Tarr, of the Fisheries Research Board of Canada—is shown preparing a microbiological assay of vitamin B_{12} animal growth factor to ascertain whether the amount of this factor in fish products can be increased.

MUSCLE LIPIDS OF TUNA

by

H. S. OLCOTT, J. FROINES and C. Y. SHUSTER

Some newer methods of analysis are being applied to a study of the muscle lipids of tuna fish with particular reference to the phospholipid components. Skeletal muscle obtained from fresh or frozen tuna is freed from red meat, and extracted with chloroform-methanol by the Folch procedure as modified by Bligh and Dyer (*Can. J. Biochem. and Physiol.* 37, 911 (1959)). The total lipid extract is then fractionated by elution from a silicic-acid column with chloroform containing increasing amounts of methanol. The order of elution is as follows: neutral glycerides, sterols, cephalins, phosphoinositides, lecithins, lysolecithins, and sphingomyelins. Some minor fractions are not yet identified. The separate eluates are evaporated to dryness under nitrogen, weighed to determine yield, pooled when desirable, and subjected to analysis by infra-red absorption spectrophotometry, and for phosphorus, ester, and plasmalogen content, fatty acid composition, iodine value and nitrogenous constituents. Infra-red absorption peaks at 5·8, 6·5–6·6, 9·0–9·5, 9·8–9·9μ (microns) help to identify cephalins; at 2·9 μ, to identify phosphoinositides; at 2·9, 5·8, 9·0–9·5, 9·8, 9·9, 10·3 μ to identify lecithins; and at 5·8, 6·3–6·8, 10·3 μ to identify sphingomyelins (cf. Nelson and Freeman, *J. Biol. Chem.* 234, 1375 (1959)). Excellent spectra for qualitative work are obtained with thin films of each fraction between sodium chloride discs.

The fatty acid composition is determined by means of gas liquid chromatography. The fractions are hydrolysed, the fatty acids recovered, and changed to methyl esters. They are analysed with a column packed with diethylene glycol succinate polymer (DEGS) on fire brick, and held at 180° and 210°. Helium is the carrier gas. Detection is by thermal conductivity cell.

Preliminary data have been obtained with a small number of albacore and yellow-fin tuna muscle samples. The total lipid content has ranged from 0·4 per cent to 10 per cent of the total wet weight. Neutral lipid accounted for most of that over 0·25 per cent. Of the phospholipid fractions the lecithins were the most abundant (40–60 per cent); the cephalins were present in amounts of one-third to one-half as much (17–25 per cent). Sphingomyelins were a minor fraction (7–15 per cent), and phosphoinositides accounted for less than 5 per cent. A considerable portion (10–30 per cent) of the lecithin and cephalin fractions were in the form of plasmalogens.

Preliminary fatty acid determinations indicate that palmitic acid accounts for most of the saturated fatty acids in the neutral fat and in the lecithins, but that stearic acid is the more abundant in the cephalins. Further comparisons of fatty acid composition will be presented.

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LES LIPIDES MUSCULAIRES DU THON

Quelques nouvelles méthodes d'analyse ont été appliquées à l'étude des lipides musculaires du thon avec une référence particulière aux composants phospholipidiques. Des muscles du squelette, retirés de thons frais ou congelés, sont nettoyés de leur chair rouge et soumis à une extraction à l'alcool méthylique chloroformé selon le mode opératoire de Folch, modifié par Bligh et Dyer (*Can. J. Biochem. and Physiol.* 37, 911 (1959)). L'extrait lipidique total est alors fractionné par élution sur colonne à l'acide silicique avec du chloroformé contenant des quantités croissantes d'alcool méthylique. L'ordre d'élution est le suivant: glycérides neutres, stérols, céphalines, phosphoïnositides, lécithines, lysolécithines et sphyngomyélines. Quelques fractions mineures n'ont pas encore été identifiées. Les élutés séparés sont pesés pour déterminer la quantité produite, placés ensemble lorsqu'il est nécessaire et soumis à l'analyse par spectophotométrie d'absorption à l'infra-rouge et pour l'étude de la teneur en phosphore, en ester et en plasmalogène, de la composition en acides gras, de l'indice d'iode et des constituants azotés. Les pointes de l'absorption à l'infra-rouge à 5,8; 6,5–6,6; 9,0–9,5; 9,8–9,9 μ (microns) permettent d'identifier les céphalines: à 2,9 μ, les phosphoïnositides: à 2,9; 5,8; 9,0–9,5; 9,8; 9,9; 10,3 μ les lécithines: et à 5,8; 6,3–6,8; 10,3 μ les sphyngomyélines (Nelson et Freeman, *J. Biol. Chem.* 234, 1375 (1959)). On a obtenu d'excellents spectres pour l'étude qualitative avec des couches minces de chaque fraction entre des disques de chlorure de sodium.

La composition en acides gras est déterminée au moyen de la chromatographie gazliquide. Les fractions sont hydrolysées, les acides gras récupérés et transformés en méthyl-esters. Ils sont analysés avec une colonne bourrée au succinate polymérisé de diéthylène-glycol (DEGS) sur réfractaire et maintenue à 180° et 210°. L'hélium est le gaz de transport. La détection est faite par une cellule de conductivité thermique.

Les données préliminaires ont été obtenues avec un petit nombre d'échantillons de muscles de thon albacore et de thon à nageoires jaunes. La teneur totale en lipides variait de 0,4% à 10% du poids total à l'état humide. Les lipides neutres intervenaient principalement au-dessus de 0,25%. Dans les fractions des phospholipides, les lécithines étaient les plus abondantes (40–60%), et les céphalines se présentaient en quantités de l'ordre de un tiers à un demi des précédentes (20 à 25%). Les sphyngomyélines intervenaient en fraction moindre (7–15%) et les phosphoïnositides pour moins de 5%. Une proportion considérable (10–30%) des fractions de lécithine et de céphaline se trouvait sous la forme de plasmalogènes.

Les déterminations préliminaires des acides gras indiquent que l'acide palmitique intervient principalement parmi les acides gras saturés dans les graisses neutres et dans les lécithines, mais que l'acide stéarique est le plus abondant dans les céphalines. On présentera d'autres éléments de comparaison de la composition en acides gras.

Cette étude a été subventionnée par des fonds accordés par le Saltonstall-Kennedy Act et administrés par un agrément coopératif entre le Fish and Wildlife Service et l'Université de Californie.

LIPIDOS DEL TEJIDO MUSCULAR DEL ATUN

Algunos métodos más modernos de análisis se aplican a un estudio de los lípidos del tejido muscular del atún, con especial referencia a los fosfolípidos. El músculo esquelético obtenido de atún fresco o congelado se separa de la carne roja, y se extracta con cloroformo-metanol por el procedimiento de Folch modificado por Bligh y Dyer (*Can. J. Biochem. and Physiol.* 37, 911 (1959)). El extracto de lípidos total se fracciona por elutriación en columna de ácido silícico con cloroformo que contiene cantidades crecientes de metanol. El orden de elutriación es el siguiente: glicéridos neutros, esteroles, cefalinas, fosfoinosítidos, lecitinas, lisolecitinas y esfingomielinas. Todavía no se han identificado algunas fracciones menores. Los elutriados separados se pesan para determinar el rendimiento, se combinan cuando conviene, y se analizan por espectrofotometría de absorción de rayos infrarrojos, y para determinar el contenido de fósforo, ésteres y plasmalógeno, composición de ácidos grasos, índice de yodo y constituyentes nitrogenosos. Los máximos de absorción de rayos infrarrojos a 5,8; 6,5–6,6; 9,0–9,5; 9,8–9,9 μ (micrones) ayudan a identificar cefalinas: a 2,9 μ identifican fosfoinosítidos: a 2,9; 5,8; 9,0–9,5; 9,8; 9,9; 10,3 μ identifican ecitinas: y a 5,8; 6,3–6,8; 10,3 μ identifican esfingomielinas (Nelson y Freeman, *J. Biol. Chem.* 234, 1375 (1959)). Se obtienen excelentes espectros para la labor cualitativa con capas delgadas de cada fracción entre discos de cloruro sódico.

La composición de los ácidos grasos se determina por medio de cromatografía a través de gas y líquido. Las fracciones se hidrolizan, los ácidos grasos se recuperan y se cambian a ésteres de metilo. Se analizan en columna llena del polímero succinato glicol dietileno en ladrillo refractario y se mantienen a 180° y 210°. Se emplea helio como gas vector. La detección se hace por célula de conductividad térmica.

Los datos preliminares se han obtenido con un pequeño número de muestras de tejido muscular de albacora y atún de aleta amarilla. El contenido de lípidos total ha variado de 0,4 a 10% del peso en fresco total. A los lípidos neutros ha correspondido la mayor parte de la cantidad superior a 0,25%. De las fracciones fosfolípido, las lecitinas son las más abdundantes (40–60%); las cefalinas están presentes en cantidades superiores en un tercio a una mitad (20–25%). Las esfingomielinas constituyen una fracción menor (7–15%), y los fosfoinosítidos representan menos del 5%. Una parte considerable (10–30%) de las fracciones lecitina y cefalina se encuentran en forma de plasmalógenos.

Las determinaciones preliminares de los ácidos grasos indican que al ácido palmítico corresponde la mayor parte de los ácidos grasos saturados en la grasa neutra y en las lecitinas, pero que el ácido esteárico es el más abundante en las cefalinas. Se presentarán otras comparaciones de la composición de ácidos grasos.

Esta labor se costeó con fondos obtenidos en virtud de la ley Saltonstall-Kennedy administrados por medio de un acuerdo de colaboración entre el Servicio de Pesca y Caza y la Universidad de California.

The richness of tuna flesh has caused an expanding development in this fishery in suitable waters over the last decade. The view shows a heavy shipment of frozen tuna displayed on the Tokyo market. Tuna fishery is now one of the greatest in the world.

THE EFFECT OF LINOLEIC AND LINOLENIC ACIDS ON THE SOLUBILITY OF COD ACTOMYOSIN

by

FREDERICK KING, MARGARET ANDERSON and MAYNARD STEINBERG

During frozen storage of fish muscle, its myofibrillar proteins gradually become inextractable and the flesh becomes tough. Drying of fresh fish muscle produces similar results. Although it is generally believed that protein extractability and texture of the flesh are causally related, there is very little information concerning the mechanism by which actomyosin aggregates and becomes inextractable. The present research has investigated the relationship of fatty acids to actomyosin solubility.

Linoleic and linolenic acids were added volumetrically to each of the following: (1) aliquots of soluble cod actomyosin; (2) aliquots of total soluble cod protein; and (3) the solvent buffer just before extraction of total soluble protein from replicate samples of cod flesh. The concentrations of added fatty acid were similar to the estimated total fatty acid content of frozen-stored cod flesh. Total soluble protein extracts contained approximately three parts of actomyosin to one part "easily soluble protein", and were prepared by a method based on that of D. G. Ellis and P. M. Winchester (*J. Fish Res. Bd. Canada*, **16**, (1) 33, 1959). Actomyosin extracts were prepared by a method based on that of J. J. Connell (*Biochem. J.* **69**, (1), 5, 1958).

The extent of actomyosin insolubilization was measured immediately after preparation of the extract or after storage of the blends for one to four days at 39°F (4°C) (Fig. 1). This was done by measuring the protein unsedimented by centrifugation at 10,000 times gravity for 20 minutes. In all experiments controls were treated in a manner identical to the experimental samples, with the exception that they did not contain added fatty acid. Soluble protein content of the controls was essentially unchanged during storage at 39°F (4°C).

The presence of added fatty acid during extraction reduced the amount of actomyosin obtainable. The addition of fatty acid to an extract of actomyosin resulted in a loss of soluble actomyosin. Stoichiometric data were obtained which demonstrated that linoleic and linolenic acids insolubilized actomyosin at different rates. From these data, and from data obtained in experiments with fatty acid esters and non-ionic surfactants, it is concluded that protein binding by dissociated fatty acid anions is significant as part of the mechanism by which fatty acids insolubilize actomyosin.

Although all of the available evidence supports a conclusion of causal relationship, it has not yet been shown that fatty acids act on actomyosin *in situ* so as to decrease protein extractability from cod muscle. Since linoleic and linolenic acids insolubilized extracted actomyosin at different rates, it is presumed that species differences in actomyosin stability (for example, rabbit *vs.* cod) are related to differences in the composition of their muscle fatty acids.

L'EFFET DES ACIDES LINOLEIQUE ET LINOLENIQUE SUR LA SOLUBILITE DE L'ACTOMYOSINE DE LA MORUE

Durant l'entreposage en congélation du muscle de poisson, ses protéines myofibrillaires deviennent de plus en plus difficilement extractibles et la chair devient coriace. Le séchage du muscle de poisson frais produit des résultats identiques. Bien qu'on pense généralement que l'extractibilité des protéines et la texture de la chair soient liées d'une façon causative, on a trop peu d'information sur le mécanisme par lequel l'actomyosine s'agrège et cesse d'être extractible.Cette étude a recherché les relations entre les acides gras et la solubilité de l'actomyosine.

On a ajouté volumétriquement des acides linoléique et linolénique (1) à des parties aliquotes d'actomyosine soluble de morue, (2) à des parties aliquotes de protéine soluble totale de morue et (3) au solvant tampon juste avant d'extraire la protéine soluble totale d'échantillons multiples identiques de chair de morue. Les concentrations d'acide gras ajouté étaient identiques à la teneur estimée totale en acide gras de la chair de morue entreposée sous congélation. Les extraits totaux de protéine soluble contenaient approximativement trois parts d'actomyosine pour une part de "protéine facilement solubilisée", et ils avaient été préparés par une méthode basée sur celle de D. G. Ellis et P. M. Winchester (*J. Fish Res. Bd. Canada*, **16**, (1) 33, 1959). Les extraits d'actomyosine avaient été préparés de leur côté par une méthode basée sur celle de J. J. Connell (*Biochem. J.* **69**, (1) 5, 1958).

L'importance de l'insolubilisation de l'actomyosine a été mesurée immédiatement après la préparation de l'extrait ou après l'entreposage des mélanges durant un à quatre jours à 39°F (4°C) (Diagram 1). On l'effectuait par la mesure de la protéine non sédimentée par centrifugation à 10 000 *g* durant 20 minutes. Dans toutes les expériences, des témoins étaient traités de la même manière que les échantillons expérimentaux, mais ils ne contenaient pas d'acides gras ajoutés. La teneur en protéine soluble des témoins restait fondamentalement inchangée durant l'entreposage à 39°F (4°C).

La présence d'acide gras ajouté durant l'extraction réduisait le montant d'actomyosine qu'on pouvait obtenir. L'addition d'acide gras à un extrait d'actomyosine se traduisait par une diminution de l'actomyosine soluble. On a obtenu des données stoechiométriques qui ont montré que les acides linoléique et linolénique insolubilisaient l'actomyosine à des taux différents. Depuis ces données, et depuis des données obtenues dans des expériences avec des esters d'acides gras et des agents tensioactifs non-ioniques, on a conclu que la liaison des protéines par des anions d'acides gras dissociés est importante comme élément du mécanisme par lequel les acides gras insolubilisent l'actomyosine.

Quoique tous les faits amènent à conclure à une relation causative, on n'a pas pu montrer encore que les acides gras agissent sur l'actomyosine *in situ* de façon à diminuer l'extractibilité des protéines du muscle de morue. Puisque les acides linoléique et linolénique insolubilisent l'actomyosine extraite à des vitesses différentes, on peut émettre l'hypothèse que certaines différences spécifiques observées dans la stabilité de l'actomyosine (par exemple: lapin *vs.* morue) sont liées à des différences dans la composition de leurs acides gras musculaires.

EFECTO DE LOS ACIDOS LINOLEICO Y LINOLENICO EN LA SOLUBILIDAD DE LA ACTOMIOSINA DEL BACALAO

Durante el almacenamiento de tejido muscular de pescado congelado, las proteínas de las miofibrillas se hacen cada vez más difícilmente extractables y la carne se pone coriácea. La desecacion del tejido muscular de descado fresco produce resultados análogos. Aunque se cree en general que la extractabilidad de la proteína y la textura de la carne están ligadas de manera causativa, se tienen muy pocos datos sobre el mecanismo por el cual la actomiosina se agrega y cesa de ser extractable. En este estudio se han investigado las relaciones entre los ácidos grasos y la solubilidad de la actomiosina.

Se adicionaron volumétricamente los ácidos linoleico y linolénico a: (1) partes alícuotas de actomiosina soluble del bacalao; (2) partes alícuotas de proteínas solubles totales del bacalao, y (3) el solvente tampón inmediatamente antes de la extracción de proteínas solubles totales a partir de muestras idénticas de carne bacalao. Las concentraciones de ácido graso adicionado eran idénticas al contenido estimado

total de ácido graso de la carne de bacalao almacenada congelada. Los extractos totales de proteínas solubles contenían, aproximadamente, 3 partes de actomiosina a 1 parte de "proteína soluble fácilmente", y se habían preparado por un método basado en el de D. G. Ellis y P. M. Winchester (*J. Fish Res. Bd. Canada*, **16** (1) 33, 1959). Los extractos de actomiosina se prepararon por un metodo basado en el de J. J. Connell (*Biochem. J.* **69** (1) 5, 1958).

El grado de insolubilidad de la actomiosina se midió inmediatamente después de preparar el extracto o después del almacenamiento de las mezclas de 1 a 4 días a 39°F (4°C) (Diagrama 1). Esto se efectuó midiendo la proteína no sedimentada por centrifugación a 10.000 *g* durante 20 minutos. En todos los experimentos los testigos se trataron de la misma manera que las muestras experimentales, excepto que no contenían ácido graso añadido. El tenor de proteína soluble de los testigos permaneció fundamentalmente sin variación durante el almacenamiento a 39°F (40°C).

La presencia de ácido graso adicionado durante la extracción redujo la cantidad de actomiosina factible de obtención. La adición de ácido graso a un extracto de actomiosina produjo una pérdida de la actomiosina soluble. Se obtuvieron datos estoiquiométricos que demostraron que los ácidos linoleico y linolénico hacían insoluble la actomiosina a diferentes velocidades. De estos datos y de otros obtenidos en experimentos con ésteres de ácidos graso y de agentes tensoactivos no iónicos se llegó a la conclusión de que la ligazón de proteínas por aniones de ácidos grasos disociados es importante como parte del mecanismo por el cual los ácidos grasos hacen insoluble la actomiosina.

Aunque todos los hechos conducen a la conclusión de la existencia de una relación causativa, todavía no se ha demostrado que los ácidos grasos actúen sobre la actomiosina *in situ* de manera que disminuya la extractabilidad de las proteínas del músculo de bacalao. Como los ácidos linoleico y linolénico hacen insoluble la actomiosina extráctada a diferentes velocidades, se adelanta la hipótesis de que diferencias específicas observadas en la estabilidad de la actomiosina (por ejemplo: conejo y bacalao) están relacionadas a la composición de sus ácidos grasos musculares.

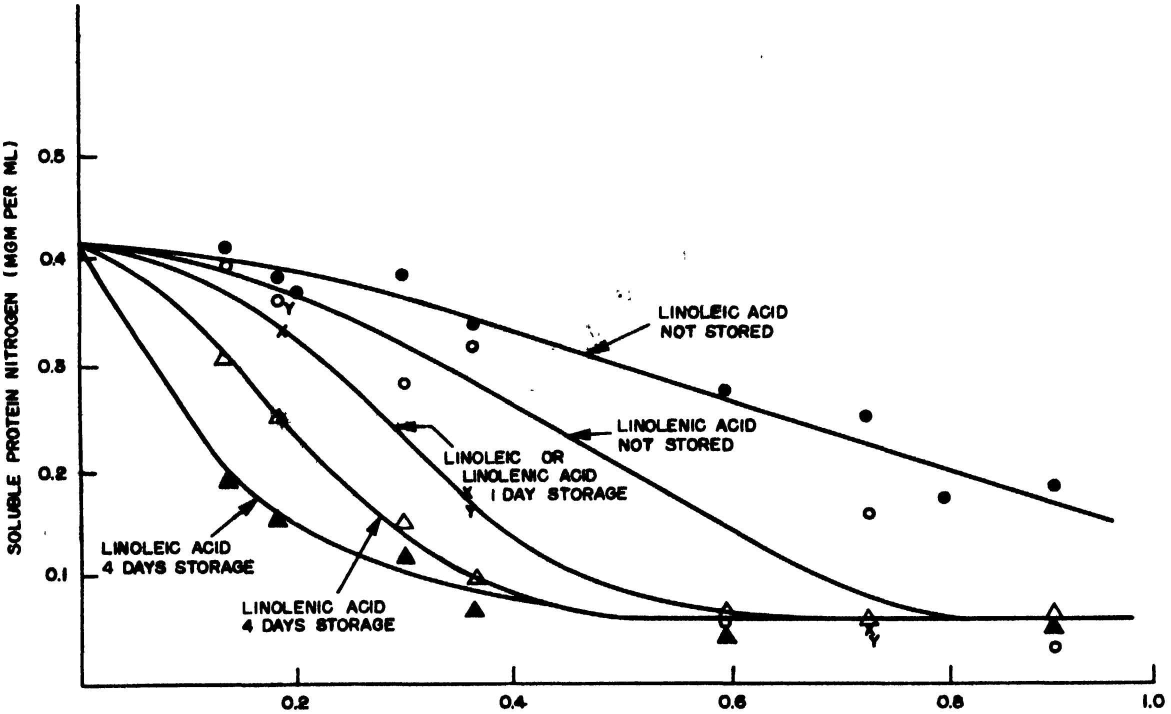

Fig. 1. Soluble protein of actomyosin sols containing added linoleic acid and added linolenic acid. Stored at 4°C for one and four days.

POLYUNSATURATED FATTY ACIDS IN FISH MITOCHONDRIA

by

T. RICHARDSON, A. L. TAPPEL and E. H. GRUGER

The purpose of this research was to determine if biochemically functional mitochondria specifically require linoleic, linolenic or arachidonic acids; to test for fatty acid involvement in electron transport; and to study the disposition of fish fatty acids in liver and heart mitochondria of fish-eating marine birds and mammals. Metabolic studies show that high levels of classical essential fatty acids (EFA) are necessary for mitochondrial function in the rat. Nutritional studies indicate that fish oils, although low in classical essential fatty acids (EFA), have EFA activity. Relative distribution and concentration of mitochondrial fatty acids from fish, mammals, and birds might indicate whether fish concentrate EFA in mitochondria or possibly utilize higher polyunsaturated homologs for mitochondrial function.

Methyl esters of fatty acids from mitochondria isolated by differential centrifugation were analysed by gas liquid chromatography. Mitochondrial cytochrome concentrations were calculated from difference spectra (Table I).

The unsaturation of mitochondrial fatty acids increased as follows: Chicken liver < beef heart < rat liver < catfish liver < carp liver < salmon liver < salmon heart. Linoleic and arachidonic acids accounted for 22·3 per cent, 51·6 per cent, 45·2 per cent, 4·5 per cent, 20·6 per cent, 4·9 per cent, 2·7 per cent of total fatty acids in these preparations, respectively. Linolenic acid was not detectable in mitochondria from chicken liver, beef heart, rat liver, and catfish liver. Molar ratios of EFA to cytochrome *c* ranged 70 to 1,051. Generally, fish mitochondria were low in total essential fatty acids, but contained high levels of $C_{20:5}$ and $C_{22:6}$ fatty acids (Table II). Chicken mitochondria contained a $C_{22\cdot 6}$ polyene (2·6 per cent). Mitochondrial linoleic acid was low in salmon liver (0·9 per cent) and salmon heart (1·1 per cent) and undetectable in catfish liver. Mitochondrial fatty acid patterns of hearts and livers of pelican, cormorant, grebe, murre, scoter, and fur seal were similar to those of fish. The main differences were the lower average of total fatty acids, and the higher average of stearic and arachidonic acids in the mitochondria of birds and seal.

The research indicates that fish mitochondria have no compulsory requirement for linoleic acid or linolenic acid; fish apparently do not concentrate EFA in mitochondria; and classical EFA do not function in mitochondrial electron transport.

LES ACIDES GRAS POLYINSATURES DANS LES MITOCHONDRIES DU POISSON

L'objet de cette recherche a été de préciser si les mitochondries dans leurs fonctions biochimiques exigent d'une façon spécifique les acides linoléique, linolénique et arachidonique; de vérifier par l'épreuve l'intervention des acides gras dans le transport d'électrons; et d'étudier la disposition des acides gras du poisson dans les mitochondries du foie et du coeur des oiseaux marins et des mammifères qui consomment du poisson. Des études de métabolisme montrent que de hauts taux d'acides gras essentiels (AGE) classiques sont nécessaires à la fonction mitochondrielle chez le rat. Des études de nutrition montrent que les huiles de poisson, bien que pauvres en acides gras essentiels classiques, ont une activité AGE. La distribution relative et la concentration des acides gras mitochondriels chez les poissons, les mammifères et les oiseaux pouvait indiquer si les poissons concentrent les AGE dans les mitochondries ou s'ils utilisent peut-être des homologues supérieurs polyinsaturés pour la fonction mitochondrielle.

On a analysé à la chromatographie gaz-liquide des esters méthyliques d'acides gras provenant de mitochondries isolées par centrifugation différentielle. Les concentrations en cytochrome mitochondriel ont été calculées sur les différences de spectres (Tableau I).

L'insaturation des acides gras mitochondriels augmentait ainsi qu'il suit; foie de poulet < coeur de boeuf < foie de rat < foie de silure < foie de carpe < foie de saumon < coeur de saumon. Dans ces préparations, les acides linoléique et arachidonique intervenaient ensemble par rapport aux acides gras totaux suivant les pourcentages respectifs de 22,3%, 51,6%, 45,2%, 4,5%, 20,6%, 4,9%, et 2,7%. L'acide linoléique n'était pas décelable dans les mitochondries du foie de poulet, de coeur de boeuf, de foie de rat et de foie de silure. Les rapports molaires d'AGE au cytochrome *c* variaient de 70 à 1051. En général, les mitochondries de poisson étaient pauvres en acides gras essentiels totaux, mais présentaient des teneurs importantes en acides gras en $C_{20:5}$ et $C_{22:6}$ (Tableau II). Les mitochondries du poulet contenaient 2,6% d'un polyène en $C_{22:6}$. L'acide linoléique mitochondriel était faible dans le foie de saumon (0,9%) et dans le coeur de saumon (1,1%) et indécelable dans le foie de silure. Les distributions d'acides gras mitochondriels dans les coeurs et les foies de pélican, cormoran, grèbe, guillemot, macreuse et otarie étaient identiques à celles du poisson. Les différences principales résidaient dans une moyenne plus basse en acides gras totaux et dans une teneur plus haute en acides stéarique et arachidonique dans les mitochondries des oiseaux et de l'otarie.

Ces recherches montrent que les mitochondries de poisson n'ont pas de besoin absolu en acides linoléique on linolénique; le poisson ne concentre apparemment pas les AGE dans ses mitochondries; et les AGE classiques n'interviennent pas dans le transport mitochondriel d'électrons.

ACIDOS GRASOS CON VARIOS ENLACES NO SATURADOS EN LA MITOCONDRIA DEL PESCADO

Tenía la investigación por finalidad determinar si la mitocondria funcional bioquímicamente requiere específicamente ácidos linoleico, linolénico o araquidónico; determinar si los ácidos grasos estaban comprometidos en el transporte de electrones; y estudiar la disposición de los ácidos grasos del pescado en las mitocondrias del corazón e hígado de aves y mamíferos marinos que se alimentan de pescado. Los estudios del metabolismo indican que son necesarias elevadas concentraciones de ácidos grasos esenciales (AGE) para la función mitocondrial de la rata. Los estudios de la nutrición demuestran que los aceites de pescado, aunque pobres en AGE, tienen una actividad en AGE. El conocimiento de la distribución y concentración relativas de ácidos grasos mitocondriales del pescado, mamíferos y aves podría indicar si el pescado concentra los AGE en sus mitocondrias o si emplea los homólogos superiores con varios enlaces no saturados para la función mitocondrial.

Los ésteres metílicos de ácidos grasos de mitocondrias aislados por centrifugación diferencial fueron analizados por oromatografía a través de gas y líquido. Las concentraciones de citocromos mitocondriales se calcularon a partir de espectros de diferencia (Table I).

La insaturación de los ácidos grasos mitocondriales aumentó como sigue: hígado de pollo < corazón de buey < hígado de rata < hígado de bagre < hígado de carpa < hígado de salmón < corazón de salmón. A los ácidos linoleico y araquidónico correspondió el 22,3; 51,6; 45,2; 4,5; 20,6; 4,9 y 2,7% de los ácidos grasos totales en los preparados anteriores, respectivamente. El ácido linoléico era indeterminable en las mitocondrias del hígado de pollo, corazón de buey, hígado de rata e hígado de bagre. Las relaciones molares de AGE a citocromos *c* variaron de 70 a 1.051. En general, las mitocondrias del pescado eran pobres en ácidos grasos esenciales totales, pero contenían fuertes concentraciones de ácidos grasos $C_{20:5}$ y $C_{22:6}$ (Table II). La mitocondria del hígado de pollo tambien contenía un ácido de varios enlaces dobles $C_{22:6}$ (2,6%). El ácido linoleico mitocondrial era escaso en el hígado (0,9%) y en el corazón del salmón (1,1%) y no se pudo encontrar en el hígado del bagre. Las modalidades de los ácidos grasos mitocondriales del corazón e hígado de pelícano, cormorán, colimbo, pájaro niño, foja y foca peletera eran análogas a las de los peces. Las principales diferencias consistían en promedios más bajos de ácidos grasos totales, y cantidades superiores de ácidos esteáricos y araquidónicos en las mitocondrias de aves y focas.

Las investigaciones indican que las mitocondrias del pescado no necesitan forzosamente los ácidos linoleico o linolénico; al parecer, los peces no concentran AGE en las mitocondrias; y los AGE no desempeñan ninguna función en el transporte de electrones mitocondriales.

TABLE I

Cytochromes in mitochondria

Mitochondria	*Cytochromes* *Moles/mg. protein* × 10^{10}		
	a	*c*	*a*
Cormorant liver	1·0	1·1	1·4
Catfish liver	1·9	1·7	2·9
Bluegill liver	1·2	1·2	1·6
Stripped Bass liver	0·2	0·3	0·3
Starry Flounder liver	0·8	0·5	1·1
Seal liver	0·8	0·8	1·2
Rat liver	1·0	1·7	1·8

TABLE II

Fatty acids in mitochondria
Mole %

Fatty acid	*Fish*	*Marine birds*	*Seal*
18 : 0	2·8 ± 0·9	18·4 ± 1·7	18·2 ± 3·0
18 : 2	0·6 ± 0·8	4·0 ± 2·2 (2·4 ± 0·7)	5·3 ± 3·2 (2·0)
20 : 4	3·4 ± 0·9	13·9 ± 5·2	14·2 ± 0·1
20 : 5	9·0 ± 1·2	10·6 ± 3·7	13·3 ± 3·1
22 : 6	16·8 ± 2·1	7·8 ± 4·3	8·4 ± 2·3

DISCUSSION

On DR. LOVERN's paper, DR. F. KING (U.S.A.) observed: The correlation between actomyosin denaturation and the rate of hydrolysis of lipids is most evident in cod. It is not clear in dogfish, sole and halibut. I suggest that, if the data in Lovern's Table XXI were to be recalculated on the basis of the weight of free fatty acids to weight of actomyosin, rather than as the weight of fatty acids as a percentage of the total lipids, the relationship for these other three species might be improved. The phospholipid content in different species of fish varies within very narrow limits. Would the correlation between protein denaturation and free fatty acids be improved, if only the free fatty acids from phospholipids were to be considered?

DR. J. A. LOVERN (U.K.): Rates of protein-denaturation vary considerably in different species. It is not certain that plotting free fatty acids against actomyosin would give different results than could be expected from plotting free fatty acids against total tissues. Only in the case of cod is the relationship established for the effect of different temperatures on the rate of denaturation of actomyosin. The data in Table XXI of my paper refer only to frozen storage, and not to storage at any temperature above freezing. The rate of freezing is very important in determining the rate of denaturation. Very rapid or very slow freezing has the greatest effect on denaturation. Also a very rapid or very slow rate of freezing hydrolysis of lipids is greatest.

DR. H. L. A. TARR (Canada): Has Dr. Lovern been able to prepare either cell-free (soluble) or "particulate" lipase of phospholipase enzymes from fish muscles? It would be a mistake to interpret the heat inactivation of any activity whatsoever as if it were always an activation of an enzyme (e.g. Bank's early work on oxidation by the supposed lipoxidase in herring muscle).

DR. J. A. LOVERN (U.K.): My work has been concerned with changes in the tissue. Some preliminary experiments with enzyme extracts were abandoned, when I found that inhibition by the bacteriostatic agents used (chloroform and toluene) was serious over the length of incubation periods involved. The phospholipase of fish muscle was very resistant to heat; it was scarcely affected at all by 30 minutes in a casserole in steam, whereas it was completely destroyed in 90 minutes. I have no information, however, on the heat stability of any lipoxidase which may be present.

DR. G. HAMOIR (Belgium): In regard to the significance of lipid hydrolysis, the correlation suggested by Canadian workers between the lipid hydrolysis and the denaturation of actomyosin is, in my opinion, improbable. When fish actomyosin or myosin are isolated from muscles which have a high content in lipids, the preparations which I get contain small amounts or no lipids, and appear less stable than the corresponding preparations obtained from warm-blooded vertebrates. There is thus no experimental evidence of somewhat stable associations between lipids or phospholipids and actomyosin. The quicker denaturation of fish muscle seems to be due to the lower stability of the internal cell structures, which is in turn due to the lower content in stroma proteins and to the instability of the protein itself. In the showing contracture, the two processes are probably largely independent: the denaturation observed in this case is very quick, while the liberation of fatty acids is much slower.

On DR. OLCOTT's paper, MR. R. SINNHUBER (U.S.A.) asked: Could carbonyl be responsible for tissue damage and for vitamin loss?

DR. H. S. OLCOTT (U.S.A.): These compounds could result in the loss of lysine and other labile constituents.

DR. T. KANEDA (Japan): I have found that the toxicity of unsaturated fatty acid is due to the presence of peroxide which is capable of inactivating enzymes in mitochondria.

DR. K. J. CARPENTER (U.K.): The lipids in fish meal were always oxidized; feeding rats on fish meal has never resulted in the production of toxic symptoms, even when meals contained highly oxidized fats.

DR. H. S. OLCOTT (U.S.A.): I did not mean to infer that meals containing fats are always toxic except within the limits given in my paper. The highly toxic peroxides are removed from fish meal during processing, and only dimers and polymers remain. Variations of animals fed on such fish meals have proved that these dimerized and polymerized fish meals are quite safe. I mention this solely in order that people may know that these constituents are present in the meal.

DR. T. KANEDA (Japan): When oils were removed from fish meal with a mixture of benzene and methanol, and the solvent-free oil fed to rats, the animals died.

MR. M. E. STANSBY (U.S.A.): If carbonyls, which are supposed to be toxic, are so ubiquitous, can they really be as toxic as has been assumed, or are hydroperoxides the real toxic agents?

DR. H. S. OLCOTT (U.S.A.): This is not yet certain. There is some evidence that carbonyls can act as pro-oxidants. If this is true, they can form hydroperoxides.

DR. L. E. OUSTERHOUT (U.S.A.): When meal is *very* fresh, it has proved to be toxic: but this toxicity disappeared upon storage of the meal. This probably corresponded to the high initial peroxide values, reported earlier, which decrease on further storage. Moreover, if the fats oxidized rather than polymerized, digestibility was much higher and might be only slightly impaired. In both cases this could proceed without residual toxicity.

Drs. B. C. Guha (India), **J. E. Halver** (U.S.A.) and **K. H. Maddy** (U.S.A.) agreed on the toxicity of meal, and requested that investigations be made on the effect of different methods of producing toxic effects in oil. They stated that toxicity of oils could be due to the destruction of tocopherols, and suggested that future studies on the toxicity of meal be made at low levels and for extended periods of time. Dr. Maddy indicated that, in an experiment where linoleic acid was injected together with an antioxidant into chickens, the animals thrived. When, however, the antioxidant was removed, the chickens showed toxic symptoms.

On **Dr. Holman's** paper, **Dr. I. W. McDonald** (Australia) asked: Will Dr. Holman comment on the use of dialysis for the separation of phospholipids from other lipids?

Dr. R. Holman (U.S.A.): I have no specific experience with these diaphragms; but Dr. Peifer has reported that they work very well.

Dr. G. Hamoir (Belgium): It seems to me that the influence of lipids on the solubility of actomyosin has been exaggerated; this opinion is confirmed by several observations which we have made. In work with rabbits, we find that fat is located in droplets, and is not in close contact with all the parts of the muscle cells. In making separations such as those of Dr. King, it was found that during centrifuging the oil rises to the top as a separate phase. It would seem, then, that except in artificial systems, such as in an experimental model, there may be little effect upon actomyosin solubility.

Dr. F. J. King (U.S.A.): It is hard to extrapolate conclusions from model systems to muscle, because there is very little information on the biochemistry and histology of fish muscle cells. We have given Dyer's theory a critical test in our model systems, and have found experimental support for his theory.

Dr. J. A. Lovern (U.K.): I cannot agree with Dr. Hamoir. So far as I know, the fat which separates upon centrifuging occurs only with oil from depots in fatty fish; this does not occur with lean fish, such as cod, with which Dr. King worked. Phospholipids do not rise to the top of the centrifuge. Besides, Dr. King was talking about free fatty acids; whereas Dr. Hamoir referred to the whole oil, which is an entirely different matter.

Dr. G. Siebert (Germany): How was the fatty acid added to the protein? Did the presence of surface active agents change the picture? Was any comparison made, using saturated fatty acids, and were antioxidants used?

Dr. F. J. King (U.S.A.): We added the acids volumetrically with gentle blending to aliquots of actomyosin extracts. The contents of a sealed vial of fatty acid (Nutritional Biochemical Corporation) were used immediately.

When added in concentrations equivalent to the fatty acids, esters and non-ionic surfactants did not precipitate actomyosin.

We also tried oleic acid. The results followed the same pattern in regard to degree of unsaturation mentioned in our paper for linoleic and linolenic acids. However, oleic acid tended to solidify during the storage period.

We did not use antioxidants.

Dr. R. Sinnhuber (U.S.A.): During a four-day period of reaction there must surely have been considerable oxidation.

Dr. F. J. King (U.S.A.): This may be possible. I doubt that it would have much effect, since linoleic acid, instead of linolenic acid, produced more insoluble actomyosin in 4 days at 4°C. Furthermore, their esters were ineffective under the same experimental conditions.

Dr. G. Hamoir (Belgium): I do not believe that there is a causal relationship between fatty acids and actomyosin extractibility. The content of fat in fish muscle is usually higher than that of rabbit muscle. The extractibility of fish actomyosin is always much greater than the extractability of rabbit actomyosin. If fish muscle extracts are made from mullet or carp red muscles, which contain large amounts of lipids, and if the residue is removed by centrifugation, then a large amount of lipids separates from the protein at the top of the centrifuge tubes. The lipids which do not separate under these conditions appear from electrophoretic results to be associated with the proteins remaining in solution at low ionic strength, and not with actomyosin. On the other hand, the differences observed between cod and rabbit actomyosin are obviously due to differences in the proteins themselves. This difference has been already shown by Connell in the case of myosin, and larger differences are probably to be expected in the case of actin.

Dr. F. J. King (U.S.A.): Connell has shown that cod actomyosin is much less stable than rabbit actomyosin. He has not published any other direct evidence to demonstrate a difference between cod and rabbit actomyosin molecules. Therefore, I suggest that the difference in stability might be due to species difference in the composition of fatty acids extracted with the actomyosin. It is also possible that the muscle of fatty fish contains an agent which solubilizes actomyosin.

Summing up this discussion, **Mr. J. S. McGowan** (U.S.A.) stated that in his view the earlier papers and ensuing discussion clearly showed the importance of a close study of proximate composition. But this is not enough. Industry and nutritionists need a refinement to the total constituents in each important fish, including amino acid content, vitamin content, and composition of fish lipids. It would also be helpful to know these things about the product as it reaches the consumer. Knowledge of the part that these components play in furnishing the minimum daily requirements for maintaining food health would be extremely useful to nutritionists of the world. More research should be done in this direction, and provisions should be made for publicizing the information, possibly through the creation of a data-collection and dissemination center.

Señor Hernan Caballero (Chile), commenting on the need for training courses, offered the facilities of the Centro Nacional de Capacitation (National Training Center) and the Experimental Station of the University of Concepción and the Ministry of Agriculture in Chillán, Chile.

He took the occasion to point out that numerous international courses had been held in this Center under the auspices of various international organizations, including the FAO, the OAS, and the Rockefeller Foundation.

Moreover, there were 28 industrial establishments in the vicinity of Chillán that were devoted in one way or another to preparing marine products.

Section 3: INFLUENCE OF PROCESSING

THE INFLUENCE OF REFRIGERATION AND CANNING ON THE NUTRITIVE VALUE OF FISH

by

F. BRAMSNAES

Consumption of canned or frozen fish in nutritionally depressed areas, though small today, seems likely to increase as nutritional significance of these products is recognized.

The author reviews studies on nutritional influences of chilling, freezing and canning. In most cases, he also deals with acceptability of products from these processes. In addition, the nutritional prospects for fish offal are discussed.

He finds that the nutritive value of chilled fish does not change significantly, but the degree of acceptability does. The author touches on the need for lower-keeping temperatures once fish is landed, particularly for those areas where fresh fish is unknown only a few miles inland.

In spite of the boom in frozen products since World War II, few data are found on nutritional changes due to freezing. The known (and generally slight) nutritional losses are reviewed. The author discusses organoleptic changes occurring during freezing and storage that affect acceptability. He mentions studies on protein denaturization, desiccation, rancidity, "black spot" and chemical changes.

The author reviews the basic experimental results showing that canned products are satisfactory from a nutrition point of view, discusses protein loss (in precooking, diffusion into liquid and heat damage), vitamin retention, and methods to avoid nutritional losses.

Mention is made of protein and vitamin content of fish bones and viscera, the recent development of fish-meal plants on board ship, and prospects for reducing nutritional wastage by inexpensive methods of making fish meal.

INFLUENCE DE LA REFRIGERATION ET DE L'APPERTISATION SUR LA VALEUR NUTRITIVE DU POISSON

La consommation du poisson congelé ou conservé en boîte dans les régions sous-alimentées, encore restreinte, semble destinée à s'accroître en même temps que sera reconnue l'importance alimentaire de ces produits.

L'auteur passe en revue les études concernant l'influence nutritionnelle du refroidissement, de la congélation et de la mise en boîte. Dans la plupart des cas, il examine également l'acceptabilité des produits obtenus par ces méthodes. En outre, il considère les possibilitiés alimentaires des déchets du poisson.

Il montre que la valeur nutritive du poisson refroidi ne change pas d'une façon significative, mais que son acceptabilité change. L'auteur souligne la nécessité d'utiliser des températures de conservation plus basses après débarquement du poisson, en particulier dans les zones où le poisson frais est inconnu à quelques milles seulement du bord de la mer.

En dépit du "boom" sur les produits congelés depuis la Seconde Guerre Mondiale, on n'a réuni que peu de données sur les changements nutritifs dus à la congélation. On examine les pertes nutritives connues (et généralement faibles). L'auteur commente les changements organoleptiques qui apparaissent durant la congélation et le stockage et qui affectent l'acceptabilité. Il mentionne des études sur la dénaturation des protéines, la dessication, le rancissement, le noircissement et les changements chimiques.

L'auteur passe en revue les résultats expérimentaux de base qui montrent que les produits conservés en boîte donnent une satisfaction parfaits du point de vue alimentaire; il discute la perte en protéines (au cours de la pré-cuisson, par diffusion dans le liquide et par altération thermique), la rétention des vitamines et les méthodes qui permettent d'éviter des pertes en éléments nutritifs.

Il mentionne la teneur en protéines et en vitamines dans les arêtes et les viscères du poisson, les développements récents des installations à farine de poisson à bord des navires, et les recherches pour réduire le gaspillage des aliments par des méthodes peu coûteuses de fabrication de farine de poisson.

EFECTO DE LA REFRIGERACION Y ENLATADO EN EL VALOR NUTRITIVO DEL PESCADO

El consumo de pescado enlatado y congelado en los países en los que escasean los alimentos es actualmente pequeño, pero probablemente aumentará según se vaya reconociendo la importancia nutritiva de estos productos.

El autor reseña estudios de los efectos que en el valor nutritivo tienen el enfriamento, congelación, y enlatado. En casi todos los casos se ocupa también de la aceptación de productos obtenidos por estos tratamientos y examina las posibilidades que tienen las vísceras de pescado en la nutrición.

Juzga que el valor nutritivo del pescado enfriado no cambia mucho, pero lo hace el grado de aceptabilidad. Menciona la necesidad de mantener temperaturas más bajas cuando el pescado llega a tierra, particularmente en los lugares en que el fresco es desconocido a unas pocas millas de la costa.

A pesar del rápido desarrollo de los productos congelados desde la segunda guerra mundial, existen muy pocos datos sobre los cambios nutritivos causados por la congelación. Se reseñan las perdidas conocidas, generalmente ligeras, del valor nutritivo. El autor discute los cambios organolépticos que ocurren durante la congelación y almacenamiento e influyen en la aceptabilidad. Menciona estudios de los fenómenos de desnaturalización de la proteína, desecación, rancidez, melanosis y alteraciones químicas.

El autor reseña los resultados experimentales básicos que muestran que los productos enlatados dan satisfacción del punto de viste alimentario, y discute las pérdidas de proteínas (en la precocción, por difusíon en el líquido y por efecto del calor), retención de vitaminas y cómo evitar la pérdida del valor nutritivo.

Menciona el contenido de proteínas y vitaminas en las espinas y vísceras del pescado, la reciente instalación de fábricas de harina de pescado a bordo de los barcos y la perspectiva de reducir la pérdida de elementos nutritivos encontrando métodos baratos para fabricar la harina de pescado.

FEW people depend upon a single food to supply their dietary needs. In general, fish constitutes only a small percentage of the daily diet and its nutritive importance seems comparatively small.

However, a closer study of diets in various areas of the world has revealed that many diets are deficient in certain vitamins and essential amino acids. Fish, even in small quantities, may make up for these deficiencies. Moreover, in sections of our globe where severe malnutrition and even hunger are facts, even small variations in the nutritive value of all components of the diet are of interest.

The consumption of canned and frozen food in these sections is of minor importance today. However, this situation may change in the future, and the nutritive value of these types of fish products may become of rising importance.

A detailed report at this Conference on the influence of canning and freezing is in effect unnecessary, because the subject has recently been reviewed (25). In this review fish products and closely related meat products have been excellently dealt with by Tarr, and by Lushbough and Schweigert.

The present paper will deal, not only with the *nutritive value*, but also with the *acceptability* of the products.

Statistics

In Table I are given the latest FAO figures on the relative importance of refrigerated and canned products in the world.

TABLE I

The relative importance of refrigerated and canned fish in the world
(*FAO Yearbook of Fishery Statistics*, Vol. XI, 1959)

	1955	*1957*	*1959*
	million	*metric*	*tons*
World total catch . . .	28·4	30·8	35·3
Marketed fresh	12·4	13·2	15·0
Utilized for freezing . . .	1·9	2·4	3·0
Utilized for canning . . .	2·5	2·9	3·1

CHILLED FISH

Nutritive value

Significant losses in thiamine occur during storage of fresh fish, if the fish contains thiaminase. This enzyme is present in many fresh water fishes and in a few salt water species, e.g. in the North Atlantic herring (*Clupea harengus*).

Few data are available on the amount of water-soluble vitamins carried away with the melting ice during storage of chilled fish. Novak *et al.* (42) found that there is a gradual reduction in the B-vitamin content of shrimps during ice storage. The losses amounted to about 10–40 per cent during 11 days' storage.

During storage of chilled fish, the melting ice also removes some amino acids and water-soluble proteins. If the fish stay from 10 to 14 days in ice, about 3 per cent of the total proteins may be lost (5, 15, 17). If the fish is under heavy pressure, as it is in the lower part of a trawler hold, a loss in the total weight of fish will also occur, amounting to about 8 per cent for cod after 17 days in ice (15, 19). Only small weight losses, or even slight gains in weight, are found when fish are iced in boxes.

Apart from the above-mentioned losses, chilled fish are not known to alter significantly in the strict nutritional sense. In his preceding paper, Bramstedt has mentioned the important chemical changes in proteins, peptides and amino acids which fish undergo during chilled storage. It would be interesting to know the nutritional significance of these changes.

Acceptability

The degree of acceptability, however, undergoes considerable change during chilling of fish.

Well-iced fish stay edible from 5 to 20 days after catching, depending on the species. At the later stages of its storage life, the fish has deteriorated so much that most people, if they have the choice, will not eat it. The limiting factors in lean fish are the formation of volatile nitrogen bases (ammonia, trimethylamine, etc.) and putrid odours. In fatty fish the development of rancidity is important and may even be the limiting factor (13).

In most cases the quality of the fish is satisfactory at the point of landing. In the past, distant water trawlers quite often did land subgrade or "borderline" fish, but improvements have been introduced in many instances. The results of excellent Canadian and British research work have made clear the relative importance of the various steps in the handling of fresh fish. This new knowledge has chiefly resulted in better icing techniques and more rational construction of fish rooms.

While the landed quality is generally satisfactory, this does not apply when the fish are distributed to inland consumers; here there is a great need for betterment to make fresh fish much more acceptable. Even in industrially well-developed countries, facilities for transportation and retail sale are often grossly inadequate. Much more advantage could be drawn from our knowledge that only a few degrees' difference in temperature has a great influence on the keeping quality of fresh fish. Improvement is called for, particularly with the aim of obtaining lower temperatures in the fish throughout the chain from fishing vessel to family kitchen (12). In many less-developed areas of the world, fresh fish is unknown a few miles inland. More extended use of ice and refrigerated transport would make good quality fish available to many people now lacking animal proteins.

FROZEN FISH

Among the various fish products offered for human consumption in recent years, the group of frozen products have had by far the most spectacular development. From practically nothing before World War II the quantity has risen to about 1,500,000 tons in 1959.

Nutritive value

In spite of the large-scale commercial application of freezing, only a few data are available on changes in nutritive value during freezing and frozen storage of fish.

Proteins

The changes appear to be slight and mostly connected with losses of nutrients in the drip which is produced during thawing. The drip is 5–15 per cent of the total weight depending on the quality of the frozen fish. Fish which have been stored several days before freezing produce more drip than fresh-frozen fish. Frozen fish stored for a long time, or stored at high temperatures, exude more liquid when thawed than fish stored for a short period or at low temperatures. The same applies to slow-frozen fish versus quick-frozen fish (41).

The proteins of fish denature during freezing and frozen storage. The denaturation is accompanied by a decrease in salt-soluble protein (48). The rate of decrease diminishes if the storage temperature is lowered (18).

The denaturation does not seem to alter the nutritive value of the proteins. Dunn *et al.* (16) published the results of amino acid analyses carried out in two different laboratories on identical samples of the edible portion of fresh, raw, freeze-dried and frozen Pacific sardines (Table II). The samples were stored for 44 days.

TABLE II

Percentages of amino acids in identical sardine samples assayed in two laboratories (calculated as percentage of dry weight) (16)

	Fresh (Acid Hydrolyzate)[1]		*Freeze-dried*[2]		*Frozen*[2]	
Amino acid	*A*[3]	*B*[3]	*A*	*B*	*A*	*B*
Arginine	3·1	3·1	2·9	3·1	2·9	3·2
Aspartic acid	5·1	—	4·7	—	4·8	—
Glutamic acid	7·0	—	6·7	—	7·1	—
Glycine	2·9	—	—	—	—	—
Histidine	3·0	2·9	2·8	2·7	2·8	2·8
Isoleucine	2·7	2·7	2·5	2·5	2·6	2·5
Leucine	4·1	3·9	3·8	3·8	3·9	3·8
Lysine	4·6	4·3	—	4·3	4·5	4·4
Methionine	1·7	1·3	1·5	1·5	1·6	1·6
Phenylalanine	2·1	2·1	2·0	1·9	2·1	2·0
Threonine	2·4	2·6	2·2	2·4	2·3	2·4
Tryptophan	0·5	0·5	0·6	0·4	0·6	0·4
Valine	3·0	3·0	2·9	2·7	2·9	2·8

[1] Samples prepared at University of California, Los Angeles.

[2] Samples prepared at University of California, Los Angeles, but hydrolysed independently in the two laboratories.

[3] Microbiological assays carried out at: (A) University of California, Los Angeles, (B) University of Wisconsin.

The treatment had no significant effect on the amino acid composition of the materials. These results, obtained after a chemical hydrolysis of the protein, do not prove that the biological value is unchanged. However, it is generally considered that this is so. The Norwegian Fisheries Research Institute compared frozen cod fillets with raw and cooked fresh cod meat in rat experiments; they found, in all cases, that digestibility and net protein utilization were of the same order, about 100 per cent and about 80 per cent respectively (40).

Vitamins

Provided that oxidation of the fats is prevented, vitamin A is stable during freezing and storage. Booher *et al.* (7) found the same content in raw and frozen oysters. No data seem to be available on vitamins D, E and K.

Some losses of B-vitamin occur in the storage of frozen fish, but the overall retention is good. Pyke and Wright (47) found 80 I.U. per 100 g. frozen salmon, but only 10 I.U. per 100 g. canned salmon.

Hoogland (27) determined thiamine, riboflavin, niacin, pantothenic acid and cobalamin in cod and haddock. He examined raw fish and fillets, unfrozen, fresh-frozen and stored 1, 3 and 6 months. He found a considerable variation in the vitamin content of one type, but no significant difference between the values for fresh and frozen fish.

The results from experiments with meat may be of some guidance. Lehrer *et al.* (32) reported that pork chops stored for 6 months at −18°C and −26°C retained 60 per cent of the thiamine originally present, 69 per cent of the riboflavin, and 100 per cent of the niacin. No significant differences in retention were observed for the two temperatures. Westerman *et al.* (56) found a thiamine retention in pork of 80 per cent and 67 per cent after 8 and 24 weeks at −18°C, and slightly higher values for riboflavin, niacin and pantothenic acid.

There has been little work published on the loss of vitamins in the drip. Again meat may serve as an example. Pearson *et al.* (44) reported that approximately 12 per cent of the thiamine, 10 per cent of the riboflavin, and 15 per cent of the niacin were lost in the drip from frozen beefsteaks.

Acceptability

In contrast to the favourable position of frozen fish regarding nutritive values, there are many problems connected with the organoleptic changes which this type of food undergoes during freezing and storage.

The denaturation of the proteins, already mentioned, is perhaps the most serious change, because it seems so difficult to control. No explanation of the mechanism behind it has yet been given. The organoleptic changes are dryness and toughness, by which frozen fish are easily distinguished from fresh fish. The influence of temperature can be seen from Fig. 1 (18). His experiments seem to indicate that temperatures below −25°C would solve the problem. This is not the case, however,

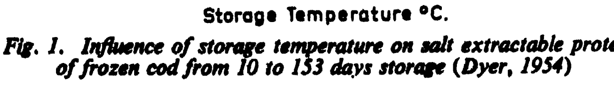

Fig. 1. Influence of storage temperature on salt extractable protein of frozen cod from 10 to 153 days storage (Dyer, 1954)

since alterations in the proteins (which are apparently not measured by the decrease in salt solubility) take place even at −25°C (26). However, if −25°C to −30°C were used in handling and storage of frozen fish instead of −18°C, which is common today, a large part of the denaturation problem would be solved. At the same time the industry would solve its problems of rancidity. As early as 1945, Banks (4) pointed out that temperatures of about −30°C are necessary for safe storage of frozen herring. Normally rancidity is considered to be a problem only with fatty fish. However, oxidation, which is the cause of rancidity, is at least responsible for one other change, namely bleaching of pigments. In frozen shrimp this bleaching is followed by a loss of flavour.

Desiccation is also a problem. It enhances both protein denaturation and oxidation. Fish stored unwrapped are normally glazed. An antioxidant glaze containing ascorbic acid is somewhat more effective than an ordinary water glaze (46, 52). Desiccation is minimized by designing cold storage rooms which will maintain a high relative humidity in the air. For this purpose, jacketed storage rooms have been built in several countries (28).

When frozen fish are packed in cartons, in-package desiccation will occur during storage. With completely filled packages this is not a serious problem; but with many products complete filling is not possible. Measures of preventing rancidity and bleaching, when sufficiently low temperatures are not available, are the use of antioxidants or packing in vacuum or in an inert gas. Tarr (50) recorded favourable results from the use of ascorbic acid as an antioxidant. It is used in practice today in Canada, where an ascorbic acid-carrageen glaze is used on frozen salmon fillets (53), and in Denmark, where an ascorbic acid dip is used in the frozen trout industry (8). For cleaned, frozen trout, a dip of 1 minute in a ½ per cent solution is sufficient to retard the onset of rancid flavour and the treatment leaves no off-taste from the acid (10). One of the most positive methods of preventing rancidity is by exclusion of oxygen (11, 51). Vacuum packing in plastic foil bags will prevent both fat oxidation and in-package desiccation (9). So far this method of packaging is commercially used for shrimp and trout with success.

An alteration, which also effects the acceptability of some frozen products, is the occurrence of "black spot" in crustaceans. Investigations by Fieger *et al.* (20) have shown that an enzymatic oxidation reaction is the cause of the discoloration, and that changing the redox potential by adding small amounts of bisulphite will prevent "black spot".

Finally it should be stressed that much more fundamental work needs to be done regarding the mechanism of fat oxidation in fish and the changes in proteins. Such work might also explain why the flavour of most frozen fish is bland and insipid compared with that of fresh fish. During storage the insipidity is changed into what best may be called "frozen fish flavour". Tanikawa and Motohiro (49) have found chemical differences between fresh and frozen fish.

CANNED FISH

Nutritive value

About 25 years ago it became an established fact that canned food is rich in nutritive value and, on the whole, as good as food prepared by the housewife from the same raw materials.

Some of the basic experiments from that period were:

(1) Kohman *et al.* (29), feeding canned food exclusively to rats up to the tenth generation and to guinea pigs up to the eighth generation, found that canned food could satisfy all the nutritional requirements. Among other things they examined reproduction and bone formation. In repeated experiments they compared canned food with home-prepared food, and found that processed food led to even better growth and reproduction than the home-prepared food.

(2) During the French East-Greenland expedition in 1932–33 the 15 men in the team lived for 13 months mainly on canned food suitably selected. None of the men showed any vitamin deficiency symptoms (37). The existence of the "maladies des conserves", as asserted by Charcot, was thus denied.

(3) Machebouef *et al.* (36) fed rats solely on canned food through 14 generations, and recorded fully satisfactory growth in every respect. The same results were obtained with guinea pigs through 4 generations.

Since these basic experiments were carried out, the fractionation of the vitamin B complex has been accomplished, and methods for the determination of the various B-vitamins have been developed. Moreover, our nutritionists have improved their methods of estimating the biological values of proteins. The need for further work on canned food in nutrition was, therefore, clearly emphasized.

Proteins

The loss of proteins can be due to three possible causes, namely pre-cooking, diffusion into the liquid in the can, and heat destruction.

Pre-cooking in steam or in water is common in fish canneries. No data are available on the extent of protein and vitamin losses in this operation.

Loss by diffusion is of secondary importance, because of the coagulation of the proteins by heat. However, the non-coagulative proteins will diffuse into the liquid.

The extent to which the proteins are damaged by the heat used in canning is still a subject of research.

At least two types of reaction are of interest:

(1) Certain amino acids, for instance lysine, will react with other parts of the proteins to form intermolecular configurations from which acid hydrolysis will release the amino acids involved, while enzymes will not. Analytic methods using acid hydrolysis will, therefore, not give a true picture of the biological availability of a protein

damaged this way. Many earlier investigations of heat changes in proteins will consequently have to be re-evaluated (3).

(2) Amino acids may react with reducing sugars with resulting destruction of the amino acids (Maillard). Acid hydrolysis will not regenerate the amino acids in such cases. If casein is refluxed for 24 hours in a 5 per cent glucose solution, very significant losses of lysine, arginine and tryptophan will occur (43).

In a collaborative project, Neilands *et al.* (39) and Dunn *et al.* (16) have investigated the amino acid content of several canned fish products, and compared it with results from the raw material used. They concluded that commercial heat processing will not destroy significant amounts of amino acids found after acid hydrolysis other than cystine, which is not an essential acid. Previously Lopez-Matas and Fellers (33) compared the amino acid contents of frozen and canned swordfish. They found no difference. Beuk *et al.* (6a) studied the effects of prolonged heat treatment (24 hours at 112°C) on raw and cured pork. After acid hydrolysis there was retention of all amino acids except cystine. The above analyses of canned fish seem to indicate that the Maillard reaction in the products examined does not seriously impair the nutritive quality of the proteins. However, for the reasons already stated above, these experiments employing acid hydrolysis do not give information about availability of proteins to humans or animals. On this subject only a few data seem to be available regarding canned fish. Fontaine and Cannepin (21) compared home-cooked meat and fish with the corresponding canned products. The *in vitro* digestibility was very nearly the same in the two cases if cooking time was less than 6 hours.

Several experiments have been carried out on meat. In these it was demonstrated that slight reductions in the availability of lysine, methionine and tryptophan from meat proteins may occur during the normal heat processing of cans. The changes are correlated with the amount of heat treatment to which the meat is subjected in canning (35). This decrease in protein value seems to be due in part to the destruction of certain amino acids and in part to lower digestibility. Beuk *et al.*, (6b) found that the content of free amino acids present in the enzymatic hydrolyzate decreases during heating, and that individual amino acids are damaged to a varying extent (Fig. 2). The *in vitro* method has in the authors' opinion a tendency to exaggerate the heat effect. Diminished protein value with increased heat treatment was shown also in experiments with rats. However, the experiments were not conclusive, because the animals receiving the heated proteins did not eat as much as those getting the raw products.

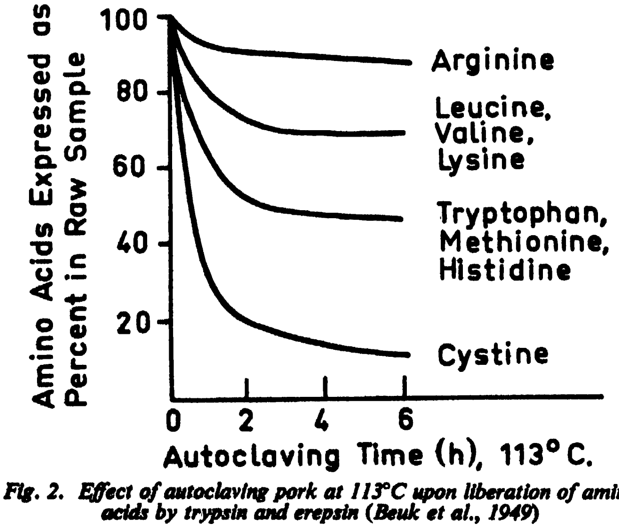

Fig. 2. Effect of autoclaving pork at 113°C upon liberation of amino acids by trypsin and erepsin (Beuk et al., 1949)

Vitamins

Higashi has already dealt with this subject in his paper, and I shall only add some supplementary information.

The diffusion of water-soluble vitamins into brine and sauce is considerable, namely up to 30–35 per cent. We find a similar situation as regards the fat-soluble vitamins in products packed in oil.

The destruction by heat of the fat-soluble vitamins is greatest for vitamin A and vitamin E, while the vitamins D and K are normally stable. Lunde (34) stressed the importance of excluding air from the can, and claimed that vitamin A was well retained if access of air was prevented, while others (2, 38) have found significantly lower vitamin A values in canned fish compared with those of raw fish. The subject needs a further study. If differences between raw and canned fish are found, the obvious place to look for losses is during the preparation of the product before filling into the can.

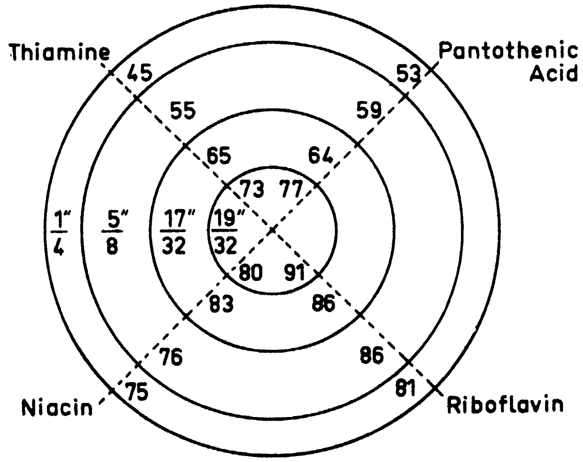

Fig. 3. Cross-sectional sampling of a 2-in. cylinder of meat mid-distant from ends of a 2½-lb. can. Processed 148 minutes at 235°F (Greenwood et al., 1944)

Among the water-soluble vitamins, C is known to be rapidly destroyed by heat in presence of air; but it is almost totally preserved if oxygen can be excluded during canning.

Among the B-vitamins, thiamine, inositol and folic acid are heat sensitive, and losses are incurred during canning. Higashi has given us the results of some Japanese experiments where vitamin B_1 is lost to the extent of 70 per cent. Others report similar results. Table III shows an experiment by Lamb *et al.* (31). The sardines were steamed while in the cans, and the exuded water was then replaced by tomato sauce. In products in which the heat penetration is slow during retorting of the cans, the heat-labile B-vitamins are least damaged in the centre of the can and most damaged near the can wall. Fig. 3 (22) shows a typical example.

TABLE III

Changes in B-vitamins during canning of sardines (31)

	Dry solids mg./ 100 g.	*Thiamine mg./ 100 g.*	*Riboflavin mg./ 100 g.*	*Niacin mg./ 100 g.*
Raw	17·2	0·003	0·430	7·69
Steamed, 45 min. . . .	19·3	0·073	0·339	7·68
Steamed + tomato sauce .	18·0	0·068	0·364	6·90
Processed, 58 min., 252°F .	18·0	0·019	0·349	6·87

The heat damage to vitamins and proteins during heat processing can obviously be reduced if shorter sterilizing time is employed. With products where the heat penetration is fairly rapid, high-short processing is advantageous. An interesting aspect in this connection is that, while the destruction of the vitamins follows the normal rate for chemical reactions (i.e. 2–3 times faster at 10°C higher temperature), the lethal effect on bacteria of the same rise in temperature increases about ten times (14). Fig. 4 illustrates this.

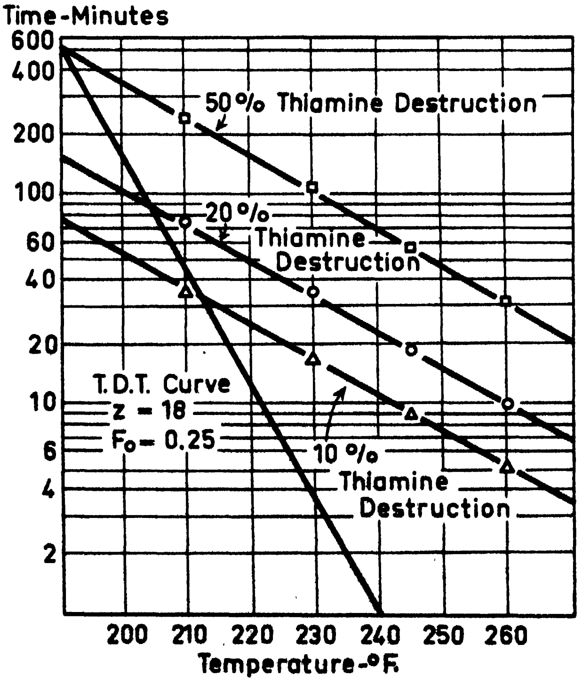

Fig. 4. Effect of time and temperature on destruction of thiamine and typical bacterial spores (Greenwood et al., 1944)

Under normal storage conditions canned food shows an excellent degree of stability against loss of vitamins. However, for maximum retention, canned food should be stored under cool conditions and, if under elevated temperatures, as short a time as possible. Little research has been done on canned fish. Komata *et al.* (30), investigating canned mackerel and tuna, found that during 6 months' storage at room temperature these products retained almost without any change their contents of riboflavin, niacin and B_{12}-vitamin, while a considerable amount of thiamine was lost.

Mention should be made of the extensive American work mostly on vegetables and fruits (23). In one of the experiments a study was made of the effect of 4, 8, 12, 18 and 24 months' storage at 10°, 18° and 27°C (50°, 65° and 80°F) on the ascorbic acid, carotene, thiamine, riboflavin, and niacin content of 32 different packs of 11 different canned fruit and vegetables. In general, vitamin retention was reasonably satisfactory under practically all conditions of storage. Both time and temperature of storage had an adverse effect on the vitamin content of the canned foods, the degree of effect depending on the particular food and vitamin. Retention of ascorbic acid and thiamine was effected more markedly by temperature of storage than by the period of storage, while the reverse was true for riboflavin and niacin. Of the five vitamins investigated, carotene was least affected by storage conditions. Canned foods stored at 10°C (50°F) retained a higher percentage of each of the five vitamins than those stored at higher temperatures. The minimum ascorbic acid retention observed at the end of 24 months' storage ranged from 48 per cent for apricots to 79 per cent for green asparagus; the minimum carotene retention ranged from 70 per cent for yellow corn to 84 per cent for Alaska peas; and the minimum thiamine retention ranged from 46 per cent for green asparagus to 72 per cent for sweet peas. The lowest riboflavin retention observed at the end of the 2-year storage period was 27 per cent in green beans, while the lowest riboflavin retention observed in sweet peas was 77 per cent. The minimum niacin retention ranged from 71 per cent for green asparagus to 94 per cent for lima beans.

Acceptability

The subject will not be dealt with in the present paper, and the reader is referred to the voluminous literature on this many-sided subject.

However, before passing on to the following chapter I wish to underline the fact that acceptability has hitherto played a far greater rôle in the trade in canned fish than has nutritive value.

Fish offal

Many species of fish are eviscerated and cleaned at sea, resulting in a 10–15 per cent weight loss. Higashi has already mentioned the fact that viscera may contain appreciable amounts of vitamins, and the protein value of these parts of the fish is known to be high (54).

Fish livers with a high vitamin content are normally saved, and the oil extracted either on board ship or after landing. A comparatively recent development is the use of small fish meal plants on board large trawlers, where viscera and trash fish are made into meal.

The preparation of fish for processing results in large quantities of fish offal. The cleaning losses during canning, oysters and clams excluded, range from 25–40 per cent (55).

The amount of offal in filleting plants varies from 50 to 70 per cent depending on species and season. The greater part of this offal could be used for human consumption, because it is as fresh as the parts of the fish used for canning and filleting. Ways of utilizing it would be to turn it into fish flour, fish paste, etc.

From a nutritive point of view the offal falls into two groups, the bones and the rest, of which bones constitute by far the greater part. Fish bones contain about 16 per cent crude protein. The amino acid content of this protein is however, not "well-balanced", partly because it has a high content of glycine. Almquist (1) estimates the biological value of connective tissue proteins (collagen, gelatin, etc.) to only 40 per cent of muscle tissue proteins. Practical experience of feeding fillet offal to mink indicates somewhat higher biological values.

Today fish offal is widely used for making fish meal or, if the offal comes from lean fish, for direct feeding to fur animals; in this way its nutritive value is saved. However, much offal is wasted all over the world in places where it is impossible to collect enough for making fish meal. In many of these places the latent nutritive value of the offal could be saved by turning it into acid silage (24, 45). The capital necessary for installing and running such a plant is small.

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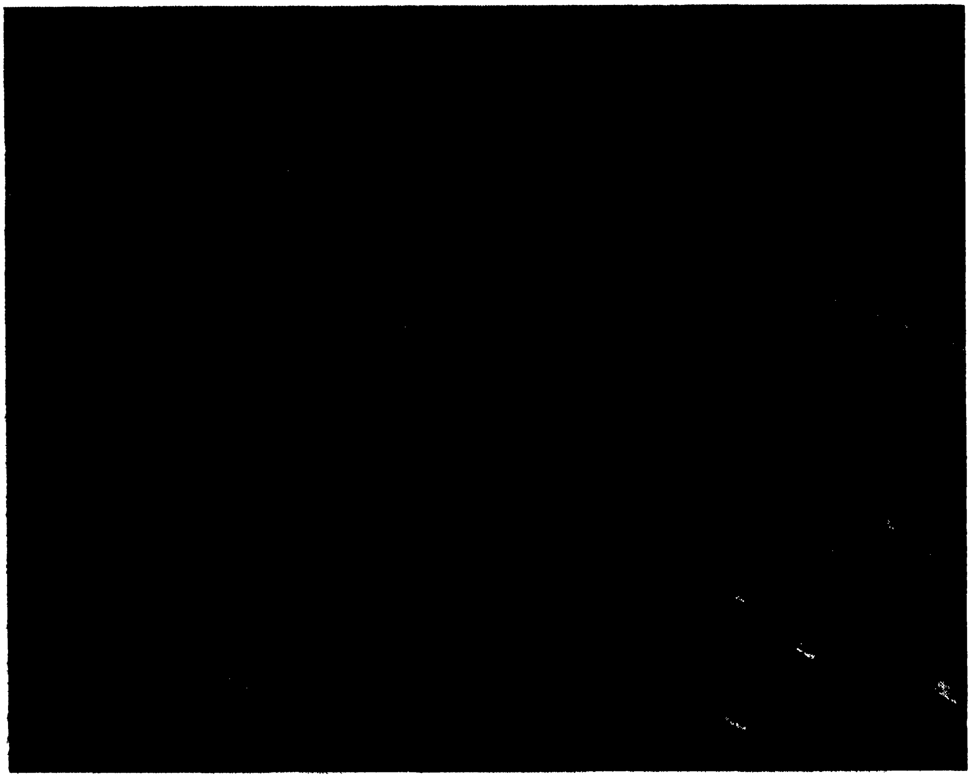

The scope and importance of canning in the fishing industry is shown by this aerial picture of one of the finest and most modern fish canning factories in the world situated in California—Star-Kist Cannery, Terminal Island. Straight-line production sees the tuna cleaned, cooked, canned, and cased ready for despatch and consumption. ***Photo: Courtesy Atlantic Ocean Fisheries.***

THE INFLUENCE OF DRYING, SALTING AND SMOKING ON THE NUTRITIVE VALUE OF FISH

by

C. L. CUTTING

Hard curing by drying, salting and/or smoking permits lengthy preservation of otherwise unusable fish, and widens its acceptability by conferring traditional flavours that are relished as condiment by many people. As transport improves with industrialization, preferences change to milder cured products, that do not keep long and therefore require careful handling; but hard cures will long continue important. Curing affects nutritive value through losses due to: (1) trimming; (2) technological changes (mostly loss of water); (3) accidents usually combined with (2) in industrial loss; (4) escape of, and (5) damage to, various nutrients; and (6) damage on storage. The few data available suggest that processing loss (4 and 5) usually has relatively little effect on overall nutritive value including protein composition and digestibility. As fish is primarily a source of protein, loss of vitamins is less important than change in gross protein content due to the other factors. Nutritional quantity being in this instance more important than quality, technological assessment of these factors in close association with industry is needed rather than further nutritional data. Many traditional products are habitually dark, oxidised, rancid, sandy, spoiled and insect-infested. Similarly mild cured products often deteriorate before consumption. If the quantitative nutritional significance of fish is to be raised appreciably, greater attention must be paid to (i) formulating and operating improved standards of quality of cured products related to people's likes and needs. Furthermore, priority should be given to (ii) intensifying technological study of curing processes with the object of maximising productive efficiency and to (iii) increasing nutritional effectiveness of raw materials by developing cured products that are directly edible by human beings as opposed to products for animal feeding. Although new processes, such as freeze-drying, are nutritionally satisfactory, the product, whilst a great improvement on wind-dried fish, is not as good as fresh or properly frozen fish. On the other hand, it can only compete with hard cured fish in developing countries, if the cost of the process is low enough and if people can be got to accept an entirely new product with less flavour.

L'INFLUENCE DU SECHAGE, DU SALAGE ET DU FUMAGE SUR LA VALEUR NUTRITIVE DU POISSON

Le traitement poussé par séchage, salage et/ou fumage permet une préservation assez longue de poissons qui seraient autrement inutilisables, et les rend plus acceptables en leur conférant des saveurs traditionnelles appréciées comme condiment par beaucoup de gens.

Avec l'amélioration des moyens de transport à la suite de l'industrialisation, la préférence du public se dirige vers des produits issus du traitement plus modéré, qui ne se conservent pas longtemps et qui demandent donc une manutention soigneuse; mais les produits issus du traitement poussé continueront longtemps à jouer un rôle important.

Le traitement affecte la valeur nutritive par des pertes dues: (1) au parage; (2) aux modifications d'ordre technique (principalement à la perte d'eau); (3) aux accidents qui les accompagnent généralement comme pertes d'ordre industriel; (4) à l'évasion de divers éléments nutritifs; (5) à leur altération; et (6) à des altérations au cours d'entreposage.

Les quelques données disponibles font penser que les pertes dues au traitement (4 et 5) n'ont d'habitude qu'un effet relativement faible sur la valeur nutrive globale, y compris la composition protéique et la digestibilité. Comme le poisson est d'abord une source de protéines, la perte en vitamines est moins importante que la modification de la teneur globale en protéines due à d'autres facteurs. La quantité nutritive étant à cet égard plus importante que la qualité, il est plus nécessaire de mieux connaître les facteurs technologiques en relation étroite avec l'industrie que de réunir d'autres données nutritionnelles. Beaucoup de produits traditionnels sont habituellement de couleur foncée, oxydés, rances, pleins de sable, gâtés et infestés d'insectes. De la même façon, les produits issus du traitement modéré s'altèrent souvent avant d'être consommés. Si l'on doit accroître d'une façon appréciable la signification nutritive quantitative du poisson, il faut prêter une grande attention à (i) établir et mettre en oeuvre des normes améliorées concernant la qualité des produits traités, en fonction des goûts et des besoins du public. En outre, il faudrait penser en priorité à (ii) intensifier la recherche technologique sur les procédés de traitement avec le propos d'amplifier au maximum l'efficicacité de la production et (iii) accroître l'efficacité nutritive des matériaux bruts en développant la production directement consommable par l'homme, par opposition à celle destinée à l'alimentation animale. Bien que de nouveaux procédés, comme la cryo-dessication, soient satisfaisants sur le plan nutritif, le produit, tout en présentant une grande amélioration sur le poisson séché à l'air, n'est pas aussi bon que le poisson frais ou convenablement congelé. D'autre part, il ne peut entrer en concurrence, dans les pays en cours de développement, avec le poisson ayant subi un traitement poussé que si son coût est assez bas et que si les populations peuvent être amenées à préférer un produit entièrement nouveau de saveur comparativement faible.

EFECTO DE LA DESECACION, SALAZON Y AHUMADO EN EL VALOR NUTRITIVO DEL PESCADO

El curado intenso por desecación, salazón y ahumado permite una conservación larga de pescado que de lo contrario no se podría emplear y lo hace más aceptable al darle sabores tradicionalmente apreciados como condimento por mucha gente.

Al mejorar los medios de transporte con la industrialización, la preferencia del público se dirige hacia productos tratados más moderadamente, que no se conservan durante mucho tiempo y que, por tanto, exigen una manipulación adecuada, pero los productos curados intensamente seguirán siendo importantes durante mucho tiempo.

El curado influye en el valor nutritivo por pérdidas debidas: (1) limpieza; (2) modificaciones de orden técnico, (principalmente pérdida de agua); (3) accidentes generalmente relacionados con (2), como pérdidas de carácter industrial; (4) pérdida de elementos nutritivos; (5) alteración de los elementos nutritivos, y (6) alteraciones durante el almacenamiento.

Los pocos datos disponibles hacen suponer que las pérdidas debidas a la elaboración (4 y 5) tienen ordinariamente nada más que un efecto relativamente pequeño en el valor nutritivo total, inclusive la composición y digestibilidad de la proteína. Como el pescado es principalmente una fuente de proteína, la pérdida de vitaminas es menos importante que las modificaciones en el contenido global de proteína, debido a otros factores. Como en este caso la cantidad nutritiva es más importante que la calidad, la evaluación técnica de estos factores en colaboración con la industria es bastante más necesaria que la obtención de datos ulteriores sobre nutrición. Muchos productos tradicionales son habitualmente de color obscuro, están oxidados, rancios, arenosos, echados a perder e infestados de insectos. Análogamente, los productos semicurados con frecuencia se echan a perder antes del consumo. Si se va a aumentar sensiblemente la importancia nutritiva cuantitativa del pescado, deberá prestarse gran atención a: (i) formular y poner en práctica normas de calidad mejorada de productos curados, con relación a las necesidades y gusto del público. Además, deberá darse prelación a (ii) intensificar los estudios tecnológicos de los procedimientos de curado, con objeto de ampliar al máximo la eficacia productiva y (iii) intensificar la eficacia nutritiva de las materias primas preparando productos curados, directamente consumibles por el hombre, en oposición a los productos destinados a la alimentación de los animales. Aunque los procedimientos nuevos como la criodesecación, son satisfactorios desde el punto de vista nutritivo, el producto, aunque representa una gran mejora sobre el pescado que se seca al aire, no es tan bueno como el pescado fresco o el congelado adecuadamente. Por otra parte, sólo puede entrar en concurrencia con pescado intensamente curado en los países en desarrollo si el coste de la elaboración es lo bastante bajo y si se puede hacer que la población acepte un producto enteramente nuevo de sabor relativamente débil.

THE exceptional perishability of fish led mankind early to evolve techniques of "curing" by drying, salting and/or smoking to preserve it from decay. These traditional processes are important nutritionally quite independently of the food value of the products; first because they permit the preservation of fish that could not otherwise be utilized and distributed in an edible state; and secondly because they increase the variety with which fish can be presented.

Although there are numerous variants, cured fish is usually severely altered in all its physical properties as a result of the process. In particular, peculiar odours and flavours may be developed in what has been described as "benign decay" (62). The flavour of some products is quite characteristic of the region, reproducible within limits, and relished by many people. However, many such products are no longer acceptable to palates conditioned to the less pronounced flavours of many urban diets. Nevertheless, curing still accounts for at least 25 per cent of the fish caught and landed throughout the world.

Curing controls in various ways the deterioration caused by micro-organisms, proteolytic enzymes, oxidation, particularly of lipids, and various non-enzymic reactions. Drying to a moisture content of below 15 per cent prevents microbial spoilage, although mould growth is completely suppressed only at 10 per cent (73, 74). Salt is a bactericide, although its effect on spoilage bacteria is slight unless the product contains more than 10 per cent, and is maximal only when tissue fluids are saturated with salt. Smoking adds chemicals which have varying bactericidal and antioxidant activity. In some processes there is the added effect of cooking which can destroy heat-labile micro-organisms and enzymes.

The characteristics of a particular product are determined to a large extent by the type and amount of deterioration that occurs before the curing process is complete, which may take anything from hours to months. Further maturation can take place during subsequent storage which, however, ultimately leads to further deterioration in edibility.

There are innumerable variations in the combination and intensity of drying, salting and smoking. The methods usually favoured for fatty fish, such as pickling under brine, and hard smoking, hinder oxidative rancidity of the highly unsaturated fish oil, whereas plain drying and dry salting are satisfactory for non-fatty species. In general, products may be divided into hard cures, suitable for long-term storage, and mild cures, which are slightly dried and contain only sufficient salt or smoke for flavouring. The latter, which are almost as perishable as fresh fish, have largely replaced the former in countries where transport and climatic conditions make keeping-quality less important than it used to be.

Drying, salting and smoking can affect nutritive value in six main ways:

1. Trimming losses

Any product that is headed, gutted, filleted, or otherwise trimmed before processing loses weight, of course; but in addition the offal rejected may include edible material which is thereby wasted. Fish vary considerably in shape; but on average something like 50 per cent of the landed weight can be separated as raw edible flesh with a filleting knife. There should be less loss of food if the consumer received cured whole fish, because flesh can be removed from the bones more completely after cooking. In some parts even viscera are regarded as edible. Trimming loss is not complete wastage, if it is used for making fish meal for example.

2. Technological loss

Drying, salting and smoking all involve a change in weight inherent in the process, due principally to the removal of water; this is not, of course, a loss nutritionally as such. As, on balance, this usually results in an overall loss in weight, rather than in gain, there is therefore in the product a concentration, or enrichment, of protein, and of such other constituents as survive the operation of factors (4) and (5).

3. Accidental loss

There are inevitably some losses involved in handling fish at every stage of any process operated under industrial conditions; as a result, for example, of fish becoming damaged, tissue torn, or roe squeezed out (50). The loss of nutrient depends on the product, scale of operation and industrial efficiency. Although reliable estimates could only be obtained by close association with industry, experience of fish smoking and drying in the U.K. leads one to suspect that it can be as high as 5 or 10 per cent, although this may be partly recoverable for fish meal for animal feeding with consequent loss to human nutrition. Accidental loss is usually combined with technological loss as *industrial loss*, and can be further concealed along with trimming loss in *overall industrial yield*, i.e. output of product/input of whole fish.

4. Escape

In some processes there can be losses due to the escape of nutrients; as when tissue fluid is extracted and flows away, as a result of osmosis, syneresis as in cooking, or autolysis.

5. Damage

There is the possibility of damage to, or destruction of, nutritive components, as a result of heat treatment, oxidation, etc.

As losses due to escape of and damage to nutrients cannot usually be separated, they may be combined together as the *processing loss.*

6. Storage loss

Finally, the stored product may be subject not only to destructive spoilage losses, but also to the inroads of various pests, such as beetles and mites. Wastage from these causes depends on the product, and is preventable if expense is incurred on suitable packaging. However, in Africa losses as high as 50 per cent occur in some instances, which have to be covered in the price of the product.

The following typical results are quoted from an unpublished report entitled "Observations on the quality and losses of dried fish from Lake Chad", by Mr. L. A. W. Haywood of the West African Stored Products Research Unit, Lagos:

Fly larvae infestation of two typical partly sun-dried *Lates niloticus* from Baga on Lake Chad, Nigeria (December 1960)

	Weight of partially dried fish[1] *(g.)*	*Number of fly larvae*[2] *inside fish (approx.)*	*Weight of larvae (approx.) (g.)*
1.	1130	1954	140
2.	1360	2523	220

[1] Fish said to have had 2–3 days drying.

[2] Mostly *Calliphoridae* or *Muscidae.*

Beetle infestation of typical dried fish on sale in Eastern Region of Nigeria, January 1961

Origin of sample	*Weight of sample (g.)*[1]	*Dermestes spp.*				*Necrobia spp.*			*Total Insects*
		Adults	*Pupae*	*Larvae*	*Total*	*Adults*	*Larvae*	*Total*	
Umuahia market	348	2	1	144	147	2	3	5	152
Umuahia market	357	1	—	73	74	1	1	2	76
Aba goods yard (ex Kano) . .	162	—	—	89	89	2	16	18	107

[1] Before removal of insects.

Only technological study of a process, and not analysis of products alone can show the relative importance of these factors, which determine nutritive value in its broadest sense.

It may fairly be deduced from the preceding papers that fish is not a particularly rich source of any vitamin (except D in fatty fish) and must therefore be considered primarily as providing protein. This is also the conclusion to be drawn from Table I which gives the calculated percentage contributions of 100 g. of fish to the average daily requirements of various nutrients for a moderately active 70 kg. man, accepting the U.S. standards adopted at Hot Springs (United Nations, 1943) and using mostly recent Norwegian analyses for cod and herring (79). Except on a diet based almost exclusively on fish, it seems that the stability of vitamins is of minor importance, as compared with the case of milk and vegetables, for example, and that changes in the content and composition of protein is the most important criterion by which the effect of a process must be judged.

TABLE I

Table for assessing relative importance of processing losses on the nutritive value of fish

Nutrient	*Normal recommended daily allowance* [1]	*Content per 100 g.*		*% of normal daily requirements supplied per 100 g.*	
		Cod	*Herring*	*Cod*	*Herring*
Calories . .	3000	70	200	2	7
Protein (g.) .	70	18	17	26	24
Vitamin A (I.U.)	5000	50[2]	200[2]	1	4
Thiamine (mg.) .	1·8	0·05	0·04	3	2
Riboflavin (mg.).	2·7	0·11	0·3	4	11
Niacin (mg.) .	18	2	4	11	22
Vitamin D (I.U.)	400	0[2]	800[2]	0	200
Calcium (mg.) .	800	20	45	3	6
Iron (mg.) . .	12	0·6	0·8	5	7
Copper (mg.) .	1·5	0·1[3]	0·3[3]	7	20
Iodine (mg.) .	0·2	0·5	0·05	250	25

(From Taarland *et al.*, 1958, except where otherwise indicated.)

[1] For 70 kg. moderately active man (United Nations, 1943).

[2] Lovern (1943).

[3] Anon. (1952) for similar species.

In this connection, it has long been recognised by food technologists that fish proteins are especially labile. Thus, fish actomyosin is particularly easily "denatured" and rendered insoluble in dilute salt solutions, for example. This denaturation, however, constitutes a technological rather than a nutritional problem because it is not associated with any loss of nutritive value. Unlike globular proteins the actomyosin molecule is already stretched out and therefore fully open to the disruptive action of enzymes. Denaturation by coagulation with salt or cooking therefore presents no advantage in accessibility to attack. Neither does it change the amino acid content appreciably. Although cooking fish results in some increase in digestibility (1) this might be attributable to its effect on the 10–20 per cent of globular proteins in fish muscle.

TABLE II Chemical composition of some Norwegian fish and fish products. (After Taarland et al., 1958)

(Figures in brackets are on a dry weight basis)

PRODUCT	CHEMICAL COMPOSITION								VITAMINS					Cals. per 100g.
	g/100g				mg/100g				µg/100g				mg/100g	
	Water	Protein	Fat	Ash	Ca	P	Fe	I	Thiamine	Riboflavin	Pantothenic Acid	B12	Niacin	
COD (Gadus callarias) Fresh (Fillet)	80.4 -	18.1 (92.8)	0.3 (1.5)	1.1 (5.6)	20 (103)	200 (1030)	0.6 (3.1)	0.5 (2.6)	50 (256)	110 (564)	180 (923)	0.8 (4.1)	2.0 (10.3)	70 (359)
Dried, salted (Klippfish)	39.5 -	37.8 (62.0)	1.0 (1.6)	22.2 (35.4)	60 (98)	300 (492)	1.6 (2.6)	-	-	230 (377)	340 (557)	3.6 (5.9)	2.4 (3.9)	160 (262)
Dried (Stockfish)	14.8 -	78.5 (91.3)	1.4 (1.6)	5.9 (6.9)	160 (186)	950 (1105)	2.5 (2.9)	1.2 (1.4)	-	240 (251)	1675 (1948)	10.0 (11.6)	7.5 (8.7)	325 (378)
Dried, reconstituted (Lütefisk)	87.9 -	11.4 (94.2)	0.3 (2.9)	0.3 (2.9)	10 (83)	90 (744)	0.5 (4.1)	0.05 (0.41)	-	50 (413)	75 (620)	1.2 (9.9)	0.2 (1.7)	50 (413)
GREENLAND HALIBUT (Reinhardtius hippoglossoides) Fresh (Fillet)	70.2 -	12.4 (41.6)	15.6 (52.4)	1.1 (3.7)	-	-	-	-	60 (201)	80 (268)	250 (840)	1.0 (3.4)	1.5 (5.0)	190 (638)
Smoked	74.6 -	13.4 (52.8)	8.8 (34.6)	3.7 (12.6)	-	-	-	-	-	170 (670)	720 (2840)	0.6 (2.4)	1.5 (5.9)	135 (532)
SALMON (Salmo salar) Fresh (Fillet)	71.0 -	20.5 (70.6)	6.2 (21.4)	1.6 (5.5)	20 (69)	200 (690)	0.8 (2.8)	0.05 (0.17)	140 (483)	220 (758)	2080 (7170)	4.0 (13.8)	8.8 (30.3)	140 (482)
Smoked	63.1 -	21.4 (58.0)	8.4 (22.8)	7.0 (19.0)	-	-	-	0.05 (0.14)	110 (298)	190 (515)	710 (1924)	7.0 (19.0)	5.0 (14.0)	160 (433)
HERRING (Clupea harengus) Large Herring														
Winter Herring Fresh (Fillet	69.4 -	16.9 (55.2)	12.4 (40.5)	1.6 (5.2)	50 (163)	250 (816)	1.1 (3.6)	0.05 (0.16)	40 (131)	300 (980)	1000 (3266)	14.0 (45.7)	4.0 (13.1)	180 (588)
Fat Herring Fresh (Fillet)	66.1 -	17.3 (51.1)	14.9 (44.0)	1.7 (5.0)	40 (118)	320 (944)	0.6 (1.8)	0.05 (0.15)	40 (118)	300 (884)	1000 (2950)	14.0 (41.3)	4.0 (11.8)	205 (588)
Cold Smoked	-	-	-	-	-	-	-	-	-	280	880	15.0	4.2	-

Kippers, Canned	62.3 -	21.1 (56.0)	13.4 (35.5)	3.5 (9.3)	140 (371)	380 (1007)	0.7 (1.9)	0.10 (0.27)	- -	370 (980)	1040 (2756)	1.5 (4.0)	4.8 (12.7)	205 (544)
Marinated, Canned	64.1 -	15.8 (44.0)	15.9 (44.3)	2.5 (7.0)	230 (641)	320 (892)	3.3 (9.2)	0.10 (0.28)	-	245 (683)	820 (2285)	9.5 (26.4)	4.7 (13.1)	210 (585)
Small Herring Fresh (Whole Fish)	76.1 -	16.9 (70.7)	4.8 (20.1)	2.4 (10.1)	280 (1170)	400 (1672)	0.7 (2.9)	0.05 (0.21)	40 (167)	300 (1254)	1000 (4180)	14.0 (58.5)	4.0 (16.7)	205 (857)
Canned, in oil	58.8 -	17.5 (42.5)	22.1 (53.5)	2.9 (7.0)	250 (606)	350 (849)	1.0 (2.4)	0.10 (0.24)	45 (109)	325 (788)	960 (2329)	8.0 (19.4)	5.7 (13.8)	270 (655)
Smoked, Canned, in oil	50.3 -	18.3 (36.8)	29.2 (58.7	3.3 (6.6)	350 (704)	440 (885)	1.9 (3.8)	0.05 (0.10)	45 (91)	270 (543)	750 (1510)	9.9 (19.9)	4.4 (8.9)	355 (714)
Canned, in tomato sauce	67.6 -	17.3 (53.3)	12.0 (37.0)	3.1 (9.6)	240 (740)	370 (1140)	2.7 8.3	0.05 (0.15)	45 (139)	300 (925)	730 (2253)	9.0 (27.8)	5.8 (17.9)	175 (540)
Smoked, Canned , in tomato sauce	66.6 -	17.1 (51.0)	12.2 (36.5)	3.5 (10.5)	360 (1077)	380 (1136)	2.9 (8.7)	0.05 (0.15)	45 (135)	290 (867)	710 (2125)	10.9 (32.6)	4.1 (12.3)	180 (538)
SPRATS (Clupea sprattus) Fresh, (Whole Fish)	68.4 -	16.8 (53.1)	10.5 (33.2)	2.5 (7.9)	280 (885)	400 (1265)	0.7 (2.2)	0.10 (0.32)	40 (127)	260 (822)	1090 (3445)	10.6 (33.5)	4.8 (15.2)	160 (506)
Smoked, Canned, in oil	50.2 -	18.6 (37.3)	29.6 (59.4)	2.6 (5.2)	250 (502)	400 (802)	1.5 (3.0)	0.10 (0.20)	30 (60)	325 (652)	800 (1604)	10.8 (21.7)	6.7 (13.4)	340 (682)
Smoked, Canned, in tomato sauce	64.5 -	16.8 (47.3)	14.3 (40.3)	3.0 (8.5)	250 (704)	350 (985)	2.7 (7.6)	0.05 (0.14)	30 (84)	325 (915)	680 (1914)	11.7 (32.9)	5.7 (16.0)	195 (549)
MACKEREL (Scomber scombrus) Spring Mackerel Fresh, (Fillet)	74.3 -	18.6 (72.3)	5.4 (21.0)	1.5 (5.8)	20 (79)	250 (972)	1.4 (5.4)	0.05 (0.19)	105 (408)	360 (1400)	1030 (4000)	12.0 (46.6)	9.4 (36.5)	125 (486)
Autumn Mackerel Fresh, (Fillet)	60 -	18.5 (46.3)	20.2 (50.5)	1.3 (3.3)	20 (50)	240 (600)	2.4 (6.0)	0.05 (0.13)	105 (262)	360 (900)	1030 (2580)	12.0 (30.0)	9.4 (23.5)	255 (637)
Smoked	61.1 -	21.5 (55.2)	10.6 (27.2)	5.8 (14.9)	-	-	-	-	-	375 (964)	520 (1337)	12.0 (30.8)	6.6 (17.0)	180 (463)
Small Mackerel Marinated, Canned	70.6 -	20.8 (70.7)	4.6 (15.6)	2.5 (8.5)	270 (918)	340 (1156)	1.9 (6.5)	0.15 (0.51)	100 (340)	400 (1360)	560 (1940)	9.4 (32.0)	8.3 (28.2)	130 (442)

TABLE III The effect of certain drying, salting and smoking processes on the nutritive quality of fish

PRODUCT	RETENTION OF VITAMINS								RETENTION OF MINERALS			PROTEIN VALUE		REFERENCE
	A	B1	B2	Pantothenic acid	Niacin	B12	Biotin	D	Ca	Fe	I	Amino acids	Digestibility	
AIR DRIED														
Stockfish			(½)	(2)	(1-)	(2)			(2)	(1)	(½)			Taarland et al. (1958)
-do- reconstituted as Lûtefisk			(¾)	(⅔)	(1/6)	(2)			(4/5)	(¾)	(1/6)			-do-
Warm air dried cooked mince (liquor lost)		½	½										No loss in rat feeding tests	Martinek & Jacobs (1943)
-do- swordfish (no loss)	2/3	½	2		¾		1/10					8 essential amino acids severely reduced others affected		Lopez-Matas & Fellers (1948)
Cooked Bombay duck												75% amino N retained	PER 63	Sawan & Magar (1961)
VACUUM DRIED														
Vacuum dried Bombay duck												85% amino N retained	PER 71	-do-
Dried in vacuum Fishmeal plant:- haddock												Biological value 83	Digestibility coefficient 85	Maynard & Tunison, (1932)
-do- menhaden												-do- 76	-do- 78	-do-
Steam cooked strips vacuum belt dried (haddock and shad)												No loss of 10 amino acids		Proctor & Lahiry (1956)
FREEZE DRIED														
Raw Pacific sardines												No loss of 13 amino acids		Dunn et al. (1949)
Raw sticks (haddock)													PER 100	Adachi et al (1958)
Raw skinned cod fillets			1	Possibly appreciable loss	1	1								Scott & Rolfe (1959
-do- stored 2 yrs. 37°C			1	No further loss	¾	1								-do-

Cod		(4/5)	(3/5)	(4/5)	(1+)						Taarland et al (1958)
-do-									Not affected by type and degree of salting & drying		Ferreira (1951)
East Indian fish	0	0	0								van Veen (1936)
Angolan fish	(½)	(1/5)		(5/10)	(1 3/10)				Not affected	Rats gain more than when fed on fishmeal and nuoc mam	Adrian (1957)
Prawns									No appreciable change in essential acids		Chari & Venkataraman (1957)
MARINATED											
Mackerel (canned)	(1+)	(1+)	(¾)	(1+)	(1)	(18)	(1)	(4)			Taarland et al (1958)
Small herring (canned)		(4/5)	(¾)	(1+)	(3/5)	(6)	(5)	(2)			-do-
SMOKED (MILD)											
Haddock	2	1	1	1	1						Hoogland (1952)
Cod	1	1	1½	1	2						-do-
Kippers (canned)	1 Some loss	1		1	1	1					See Lovern (1943)
-do-		(1+)	(2¾)	(1)	¼	(3)	(1)	(3)			Taarland et al (1958)
Herring (cold smoked)		(1)	(1)	(1)	(1)						-do-
-do- (hot smoked)		(1)	(1)	(1)	(1)						-do-
Mackerel		(1)	(½)	(2/3)	(1)						-do-
Salmon	(2/3)	(2/3)	(¼)	(½)	(1 2/5)						-do-
Greenland halibut		(2+)	(3+)	(1)	(2/3)						-do-
Small herring smoked & canned in oil	(1-)	(3/5)	(½)	(¾)	(½)	(6)	(2)	(2/3)			-do-
-do- tomato sauce	(1+)	(1)	(¾)	(1)	(4/5)	(10)	(5)	(1)			-do-

Figures give proportion of original nutrient retained

1	no change
1-	slight loss
1+	slight gain
½	50% loss, etc.
( )	indicate figures derived from presumed analysis of raw material.

In general, the chief alteration caused by drying and smoking, by themselves, is loss of water, the main effect of which is an increase in protein content, and also that of any oil that happens to be present. Although there are also incidental changes, due to oxidation, etc., in some of the minor components, as well as to the oil, the overall result is an increase in food value per unit weight of fish as purchased. Salting also brings about dehydration as a result of osmotic effects, which also involve the loss of water soluble constituents and some protein along with the fluid, whilst a considerable proportion of the oil may also be lost from fatty fish. Salted fish also introduces salt into the diet, which is particularly essential physiologically in hot regions. However, in some places, such as West Africa, people prefer to have their salt and protein requirements satisfied separately and not combined in salt fish.

Losses of weight, water and various nutrients during curing can obviously vary greatly according to the type of fish, the process and the product. In general, figures for proximate analysis and vitamin and mineral content of cured fish products are few and scattered (16). Moreover, they are rather variable, as might be expected from the seasonal and other causes of variability in the composition of the raw material (discussed by Stansby in a previous paper). In addition, even for the same commodity there can be differences in treatment between one curing installation and another, from time to time and even from fish to fish within the same batch. Furthermore, products change by a process of evolution so that, for example, a kippered herring in the U.K. today is quite different from a product of the same name 40 years ago.

Isolated analyses of products may therefore be unrepresentative and unreliable. Although any figure may perhaps be regarded as better than nothing, a technologist is reluctant to accept data without adequate weighting and some knowledge of the technological and biological factors involved. It is also unwise to draw conclusions as to the effect of processing by comparing analyses of samples of a product with figures for the presumed composition of the raw material. Nevertheless, in default of more definitive data, some of the recent analyses of Taarland *et al.* (79) for Norwegian fresh, dried, salted, smoked, marinated and canned fish products have been recalculated on a water-free basis in Table II to permit tentative comparisons of mineral and vitamin content.

Not much information is available concerning the effect of processing on protein composition and digestibility. A recent paper (Orraca-Tetteh (57b) gives the data for the protein value of fish treated by modern and traditional methods, shown top of next column.

Table III collects practically all that is recorded about the effect of drying, salting and smoking on the nutritive quality of fish, including figures derived from Table II for the effect on vitamins and minerals on the assumption that the raw material had the composition given in the same table.

	Origin	*N.P.V.* (*op.*) (%)
Fresh fish	—	90[1]
Kippers (cold-smoked herring, see III.3)	U.K.	81
Stockfish (dried, see I.1)	Norway	91
Cod (salted, see II.4).	Norway	69
Catfish (*Adwen*) (smoked)	Ghana	65
Carp (*Didei*) (sun-dried)	Ghana	57

[1] Said by author to be value of D. S. Miller (1956), *J. Sci. Fd. Agric.*, 7, 337, for carefully dried fish proteins from both oily and white fish of marine origin (although Miller's paper appears to mention only one N.P.V. value higher than 80 per cent; values obtained from the biological value of the proteins of fresh-water fish, at unstated concentrations in the diet range from 72 to 89 per cent (Kuppuswarmy *et al.*, 1958). It is presumably partly on the basis of these figures that the conclusion is reached by Platt (1961) that "heating during the drying of fish and meat can cause reductions in the biological value of their proteins (which) have been known to exceed 50 per cent".

Furthermore, there has long been supposition that leprosy is in some way associated with the consumption of salt fish (e.g. *On Leprosy and Fish Eating* by Johnathan Hutchinson, published by Constable, London, 1906) to which currency has been lent recently by inducing the disease in experimental animals fed with oxidized oils.

As in processing considerable proportions of the protein, fat and substance of fish escape, from various causes, a detailed technological knowledge of the gross changes in what may be termed *nutritive quantity* is at least as important as the detailed effect on nutritive quality in considering the overall nutritional status of a process.

Table IV is an attempt to indicate how it might be possible to build up a picture of the effect of various processes on nutritive quantity, in order to obtain an estimate of the amount of solid food (including oil) that appears in the end products in relation to the maximum that could be available. There are many gaps in Table IV, some of which could have been filled with greater study; the figures included are in some cases ranges, and in others mere estimates, so that one cannot unfortunately calculate with any degree of certainty the overall nutritive loss of any process except in the case of warm-air dehydrated, cooked, minced fish, of which industrial production is nil. However, from the data of Cutting *et al.* (25), it may be calculated that in the case of cod the industrial yield could, perhaps, have been almost doubled if all losses of edible material could be eliminated:

	Commercial results	*Ideal, with no losses*
Weight of whole gutted cod	100	100
Weight of flesh removed	42·5	70
Weight of dehydrated product	6·8	12·6

The edible meat left on the bone in this instance, of course goes to enrich white fish meal for animal feeding. In spite of the incompleteness of Table IV, it may perhaps serve to underline the interconnection between the technology of fish processing and nutritional aspects.

Some cured products are eaten raw, and some after variable soaking, desalting and cooking in a variety of

TABLE IV

The effect of certain drying, salting and smoking processes on the nutritive quantity of fish

Product	*Trimming loss (% of whole fish)*	*Technological loss (= weight loss) (% of trimmed fish)*	*Escape of nutrients (% of initial weight of trimmed fish)*		*Overall industrial yield*	*% edible material lost*
			Protein	*Oil*		
Air dried						
Stockfish	20	75	0	0	—	—
Warm air dried cooked minced cod fillets	57·5	82	2	0	6·8[1]	46[1]
Warm air dried cooked minced herring fillets	45	74	1	0	15·5–17·0[1]	—
Warm air dried cooked minced whole herring	0	65	1	1	24–30[1]	—
Vacuum (VCP) or freeze-dried (AFD) raw cod fillets	>60	80	0	0	—	—
Salted						
Brined herring	5	5–10	3–5	<1	—	—
Pickled herring	5	5–17·5				
Light-cured herring	—	—	7·5	—	—	—
Pickle salted cod (fillets)	57·5	22·5	—	0	—	—
Dry-salted cod (split)	40	30	—	0	—	—
Dry-salted herring	5	15–30	1–6	—	—	—
Salmon roe	0	25–45	3–6	5–10	55–75[2]	—
Marinated herring	45	up to 40%	—	—	—	—
Salted and dried cod:						
Heavy cured	40	30	1–2	0	29[3]	—
Light cured	40	60		—	20[3]	—
Smoked						
Red herrings	0	20–25	3–5	>1	65–70[4]	—
Kippers	20–25	5–25	1	—	65[4]	
Filleted cod	57·5	5–15	1	—	40–45[4]	

Note: The additional effects of accidental losses during processing and the loss of product during storage are not included, as representative data are not available.

The detailed effects of escape and destruction of nutrients are given in Table III.

[1] Cutting *et al.* (1956). [2] Raninskaya (1958). [3] Beatty and Fougère (1957). [4] Cutting (1951).

ways that can lead to further losses or destruction of nutrients. In view of the extreme variety of dried, salted and smoked products, it is impossible to generalize about any of the processes. In the following, the chief features of the principal types of product are discussed in relation to such data as is available on their nutritive value and quality generally. Finally, an attempt is made to draw such tentative conclusions as seem permissible.

I. DRIED FISH

1. Hard cures

Natural drying by exposure to the action of sun and wind is widespread. A classic example is stockfish, made from headed cod and haddock in Norway and Iceland at least since the twelfth century and now mostly exported to Italy, West Africa and U.S.A. Drying takes several weeks to a final water content of about 15 per cent, the technological loss being about 75 per cent and protein content correspondingly high (see Table II). The product is shrunken and tough, and is usually cooked and served in Europe after prolonged softening treatment with mild alkali (see "lütefisk", Table II).

In northern countries, where atmospheric conditions sometimes freeze the fish, the process may become extremely slow freeze-drying. At the other extreme, in the tropics, sun-drying is much more rapid. Treatment can vary considerably. *Alestis* on the shores of Lake Chad is split and dried in the sun, after preliminary "fermentation" by immersion for some hours in the warm water at the edge of the Lake to develop the desired flavour. Drying is much quicker with whole, ungutted "Dilis" (*Stolephorus commersonii*), a type of anchovy in the Philippines, and Bombay duck (*Harpoden nehereus*), also a thin fish. Fatty fish are also dried, e.g. herring in Iceland and Norway, although inevitably oxidation of fat confers a rancid flavour.

The composition of the commercial product of Asia is very variable. Thus, the water content of Indian dried fish products varies from 2·5 to 17·5 per cent and the protein content from 44 to 71 per cent (49). Most such products are contaminated with sand and infested with blow fly larvae, *Dermestes* beetles and mites. Losses also occur when fish is spoiled as a result of rain.

Very little information is available as to the effect of natural drying processes on nutritive value. As there is no obvious escape of nutrients in plain drying, any processing loss may all be attributed to damage caused by the process. It may be inferred from Table II that there is some loss of B vitamins, particularly riboflavin, known to be light sensitive, in slow drying under cool atmospheric conditions, and also perhaps that niacin particularly is lost during reconstitution and cooking.

However, it could equally well be deduced from Table II that there is an increase in pantothenic acid and vitamin B_{12} resulting from drying. This may conceivably be a real effect, resulting from bacterial synthesis.

2. New dehydrated products

The object of artificial dehydration of fish is to yield a product similar to fresh fish, without the characteristic cured flavour and toughness of fish dried in air, which is not generally acceptable in Europe. The chief products available are:

(*a*) warm-air-dried, minced, pre-cooked fish, as developed in the U.K. during the 1939–45 War; and

(*b*) vacuum and freeze-dried fish, developed post-war in U.K., U.S.A. and U.S.S.R.

(*a*) **Dehydrated cooked mince.** This product was developed as an emergency food for war-time use (Cutting, Reay and Shewan (25). A dried mince has only limited acceptability in countries where people can normally obtain good fresh or frozen fish. There has therefore been no post-war commercial development. The overall industrial yield can range from 35 per cent for fatty herring dehydrated whole without trimming to 6 per cent for dehydrated lean fish fillets. The protein content of the product depended on the fat content of the fish and whether it contained heads and bones, which increase calcium and ash contents. The water content was usually between 5 and 10 per cent. The storage life of the product in a condition regarded as acceptable in U.K. was from several years at 10°–15°C (50–59°F) to 3–6 months at 37°C (98·6°F), depending on the product. No nutritional data were obtained on the British product, but the results of feeding a similar product made experimentally in U.S.A. to rats at a level of 9 per cent weight of protein in the basal diet showed that dehydration did not affect nutritive value of digestibility. However, the pre-cooking process, which involved a 30–40 per cent by weight escape of liquor, was largely responsible for a loss of about 50 per cent of the thiamine and 65 per cent of the riboflavin. About half of each was recoverable from the cooking liquors (55). Cooking liquors also contain about 4 per cent of protein (and were thus comparable with milk). In a study of the effect of this type of dehydration process on the protein, without the complication of uncertain losses on cooking, Lopez-Matas and Fellers (52) cooked minced swordfish (*Xiphias gladius*) flesh for 1½ hours in a can in boiling water, squeezed out the water, warm-air-dried the fish and dried the liquor separately and then mixed the two fractions together. This treatment significantly affected the content of 8 out of 10 essential amino acids (as determined by microbiological assay following chemical hydrolysis) and that of two others was distinctly low. The average percentage retention was 85, compared with 94 in canning. There was good retention of vitamin A, riboflavin and niacin but low retention of thiamine and biotin.

Deas and Tarr (26) noticed that red cod (*Sebastodes* sp.) dried in a thin layer for 24 hours at 100°C and hydrolysed with alkali for 10 hours at 120°C for microbiological assay had a very low tryptophane content. However, quite a different picture of amino acid composition was obtained when the product was hydrolysed along with the proteolytic enzymes of pyloric caeca.

(*b*) **Vacuum and freeze-dried fish.** As freeze-drying in a vacuum can be used to preserve bacteria, semen, etc., in viable form (albeit with the aid of glycerol) it might also be expected to produce the best possible dehydrated fish. Since 1945, therefore, considerable effort has been devoted, particularly in the U.K., to an attempt to vacuum dry and finally to freeze-dry fish as fillets or pieces of fish that really are as acceptable as fresh or frozen fish (4, 5, 31, 32, 33a, 33b). In spite of its military interest (12, 63), so far as fish is concerned the industrial achievement to date has been very slight (7, 8, 9), except possibly in Russia (80), where freeze-drying seems to play a useful part in the distribution of fish. Despite enthusiastic claims, and whatever the success achieved with other commodities, the result with fish, when examined critically, although remarkably good, still does not compare favourably with fresh or properly frozen fish (38, 89). This, however, is applying the highest possible criteria of palatability and acceptability, whereby changes are regarded as obnoxious that would scarcely be noticeable in traditionally dried fish.

Although some useful information has been obtained about the effect of vacuum dehydration and freeze-drying (also sometimes called "lyophilization") on the nutritive value of fish, results are difficult to compare because of differences in process or pre-treatment employed by different workers. Fish proteins are more labile than those of meat. For example, they are more readily digestible by trypsin *in vitro* than mammalian protein (19b). Unlike meat, too, the actomyosin in vacuum contact plate (v.c.p.) dried cod muscle fibres was never found to be contractile in the presence of ATP. When dried experimentally on a laboratory scale, however, only about one half of the ATP-ase activity was destroyed, although when contraction occurred it was much slower than in the case of meat (37).

The darkening that occurs during lengthy drying processes and on storage of dehydrated fish is also associated with an unpalatable, bitter flavour and toughening, and has a bearing on nutritive value. Colour and flavour changes are due partly to the oxidation and oxypolymerization of unsaturated fish oils and partly to Maillard reactions in fish flesh (76, 77), between sugars, chiefly glucose and ribose, and free amino acids, chiefly anserine and taurine in fresh fish and β-alanine, 1-methyl histidine and lysine in staler fish. The amounts of the reactants present depend on the species, the individual and its immediate previous history, both before and after death (40). The extent of the damage is determined by the quantity of free sugar rather than amino acid available. As this is very variable, the degree of darkening varies unpredictably from one sample to another. There are similar reactions between products of fat oxidation and basic nitrogenous constituents. The former can also react with proteins, causing loss of biologically available lysine during dehydration and storage, although the results have been rather variable. Whereas Connell (19a) found no change in the ε-amino grouping of protein lysine during the heating of v.c.p. dehydrated cod, Carpenter *et al.* (13) noticed damage on severe heating, and Jones (41) also found a loss, although it did not affect flavour.

Regarding the texture of freeze-dried fish, Connell (19a) concludes that "the reactions underlying textural deterioration are obscure". Although there is some evidence of chemical cross-linkages, it seems that a highly porous micro-structure is the most important factor favouring good texture and reconstitution properties. In fact, rapid freezing before freeze-drying leads to the formation of such small pores that reconstitution is impeded. The bulk of the water re-absorbed in reconstitution is not chemically rebound, but is merely retained by capillary forces and can therefore easily be largely squeezed out by pressure or cooking (18), with the further loss of nitrogenous substances (89).

It has long been realised that the nutritive value of fish is improved by the lower temperature resulting from the application of vacuum during drying. Thus, Maynard and Tunison (56), found that haddock (*Melanogrammus aeglefinus*), dried for fish meal in a vacuum plant, had in rat feeding experiments a digestibility coefficient of 85 and a biological value of 83 per cent, which was much higher than for the ordinary flame-drying process. The values for menhaden (*Brevoortia* sp.) were somewhat lower in each case. More recently it has been shown that Bombay duck, cooked and dried to 6 per cent water content under a vacuum is less insoluble, reabsorbs water more rapidly and completely, and has a greater retention of amino acids and a higher pepsin digest residue (p.d.r.) than when dried in an oven at 50°C (65).

Proctor and Lahiry (59) cooked ½ in. × ⅛ in. × ⅛ in. strips of haddock and shad (*Alosa* sp.) (dipped in 0·05 per cent l-ascorbic acid for 1 minute) for 10 minutes at 5 lb./sq. in. steam pressure and dried in a vacuum belt drier. Again, there was no significant loss of 10 amino acids, whereas Lopez-Matas and Fellers (52) noticed some damage as the result of dehydration of cooked minced fish. In all the above work the fish was cooked before drying which would involve escape of nutrients. Dunn *et al.* (27) freeze-dried raw Pacific sardines (*Sardinops caerulea*), and using identical samples of the edible portion, found no significant effect on the amino acid composition in microbiological assays in two different laboratories. However, as pointed out by Tarr (78), conclusions drawn from microbiological assay following chemical hydrolysis of the product are not altogether reliable, as even fish meals which have been seriously overheated and are of poor nutritive value for chicks have a normal essential amino acid composition as determined in this way.

Adachi *et al.* (1) froze haddocks 6 days old, sawed them into sticks, freeze-dried them raw, and finally packed them under vacuum in cans. The fish was then reconstituted in water for a minute, and fried for a minute at 375°F (190°C). The PDR was not affected by drying, and increased on cooking in the cases of both the fresh and reconstituted samples.

The effect of freeze-drying raw, skinned cod fillets by the U.K. prototype industrial process on the content of vitamins of the B groups was investigated by Scott and Rolfe (1959) but full details have not yet been published. After making allowance for difficulties in sampling due to the greater amounts of riboflavin, pantothenic acid and B_{12}, but not of niacin, in the brown subcutaneous muscle tissue (the relative proportion of which increases towards the tail end of a fish) they concluded that only pantothenic acid suffered appreciable loss. Even here the low values may have been due to the admitted difficulties in extraction. When stored at 37°C for 2 years at a water content of about 5 per cent under nitrogen, only nicotinic acid showed any loss (25 per cent). As the shelf life was only 3 months, B vitamins are obviously comparatively unaffected long after the product has become inedible.

3. Summary

All dried fish present protein in a particularly concentrated form.

In considering the overall effect of drying on fish, it may be concluded that although there is not much information available, the effect of traditional sun-drying on nutritive value is probably relatively slight compared with various other losses, some of them preventable, during processing and storage. However, very little seems to be known about the biological value of the severely oxidized and darkened fish products general in Africa and Asia.

It seems relevant to comment that quality and palatability of the products are often lowered by bad or uncontrolled methods of production and storage. In many cases, improved dried products could result with little or no extra expense with proper attention to quality control.

Although freeze-dried products, which are only just beginning to be produced commercially, suffer little or no change in nutritive value during production and on storage, eating quality is adversely affected as compared with fresh fish.

II. SALTED FISH

1. Salted alone

Most traditional curing methods employ salt. Salting has the following variants:

(i) brining by immersion in concentrated salt solution;
(ii) dry salting (e.g. kench cured, green salted cod, etc.);
(iii) a combination of dry salting and brine formation (e.g. as for pickled herring, etc.).

In all three methods, considerable variations are encountered in the amount of salt used. For preservation in hot climates the method of pickling (iii), is to be preferred, as it maintains the maximum salt content around the product and thus combines quick penetration with the maximum degree of preservation. It also prevents fat oxidation and infestation with fly larvae. With brining, on the other hand, brine strength falls as salting proceeds, unless there is sufficient solid salt available. Some more lightly salted cures, such as "matje" herrings, involve a certain amount of controlled fermentation to produce the desired "gamey" flavour and soft "cheesey" texture that has lost its flaky structure and fibrosity. Whereas cures containing saturated salt can keep for months, or even years in temperate climates, the lighter cures are rather an unstable commodity and require cool storage for successful marketing. Saturated salt solution, of course, has a pronounced osmotic effect on fish tissue. In addition, proteins are dissolved by dilute salt solutions, although they tend to be precipitated at high concentrations of salt.

Reay (62) showed that there are two distinct phases in the salting of herring fillets. First there is a loss of water, and therefore a loss of weight, depending on the concentration of the brine. Later, brine is sucked back into the tissues, so that in a saturated solution the weight returns to something like its original value, although the fish now contains about 20 per cent of salt.

If the fluid extracted by dry salt in the first stage is allowed to run away, as in a "kench" cure, instead of collecting as a saturated brine pickle round the fish, then the second stage cannot take place and the overall technological loss of weight remains fixed at about 30 per cent (corresponding to about 40 per cent of the original water content). Although in this case the fluid in the tissues is still saturated with salt, there is less fluid, so that the overall salt content is less.

Other workers report technological losses of 5–17·5 per cent for herrings depending on the amount of salt used and on the amount of fat in the fish (50, 82), and 15–30 per cent for cod salted in various ways (11, 17).

Obviously, with all the interchange of fluid and equilibration of constituents between fish and brine, some loss of water soluble constituents, such as minerals and vitamins of the B group, would be expected in any salting process. Furthermore, changes occur during and after salting which lead to a further loss of soluble nutrients. During the first week or two of salting there is a steady reduction in the amount of protein that can be dissolved (that is, peptized) in salt solution. Soluble nitrogen therefore decreases. However, after a time this trend is reversed as a result of proteolysis, so that on storage the protein content of the product falls and the non-protein nitrogen increases continuously. The nitrogen "lost" as amino acids, etc., in the brine likewise rises steadily. In addition, in the case of fatty fish, oil is lost and undergoes hydrolysis and oxidation. The autolysis that occurs during pickle salting results from the activity of proteolytic enzymes and micro-organisms which is an essential feature of the ripening process.

In the experiments of Reay (62) described above, the loss of oil was negligible, but the fish contained only 6·5 per cent of oil. The loss of fat-free, salt-free solid, an approximate measure of the amount of protein, ranged from 1 to 5 per cent of the fresh fish, depending on the length of time in the brine. In dry-salted fish the loss of protein never exceeded 1 per cent.

Levanidov (50) estimates the loss of soluble substances in the brine during the salting of herring as only 0·5 per cent of the initial weight of the fish. Ragulin (60), however, found that the total loss of nitrogenous substances, fat and minerals in the salting of anchovies was about 6 per cent with dry salting and increased with time, whereas it was only about 3 per cent with brine salting and did not vary much.

Technological and accidental losses during salting depend on the freshness of the raw material. When salmon roes for caviare were kept for a day at 10°C (50°F) before salting, losses increased from 10–15 per cent to 20–30 per cent of the nitrogenous substances and from 25–30 per cent to 40–50 per cent of the fat (Raninskaya (61). Protein loss could amount to as much as 6 per cent and fat to 10 per cent of the weight of the fish. Moisture loss, too, increased from 43–49 per cent to about 60 per cent and the total yield of product declined from about 75 per cent to about 55 per cent. The liquor squeezed out during the pressing of salted roes contained 1·5–7·3 per cent fat and 1·7–5·4 per cent protein along with salt and water.

Kleimenov *et al.* (45) showed that the total nitrogen of medium salted Caspian herring decreased from 3·4 per cent (corresponding to 21 per cent protein) by about 0·75 per cent (to 16·5 per cent protein) and of heavily salted by 0·5 per cent (to 18 per cent protein) during 4½ months' storage. At the same time the total nitrogen content of the brines rose, respectively, to 7–9·5 per cent and 4·5–7 per cent. There is therefore quite a considerable loss of nutrients in the brine during salting processes.

Furthermore, results obtained under experimental conditions on a small scale are liable to be different from those obtained commercially. For example, salt takes much longer to penetrate into a large compact mass of fish than it does into a small sample (67).

Van Klaveren and Vaillancourt (85) estimated that 50,000 tons per annum of waste brine from industrial cod-salting in Canada contained 0·6 per cent of proteinaceous material. This could in theory be recovered by heat coagulation to yield (after filtering, etc.) a product containing 15 per cent of protein and 1 per cent of ash, with an amino acid composition similar to muscle proteins. However, this recovery was not regarded as economically practicable. Furthermore, free amino acids remained in the mother liquor, chiefly taurine, which is one of the commonest in fish muscle.

Table II suggests that pickle salting of herrings results in about 50 per cent loss of all the B vitamins. The amounts of riboflavin and niacin retained are only about half of those given in the FAO tables (16).

The degree of purity of the salt itself has a considerable effect on the quality of the products (72). Commercially used fishery salts throughout the world frequently contain several per cent of calcium and magnesium salts as well as sulphates which can adversely affect flavour and appearance. A good fishery salt as used in Eastern Canada should contain not more than 0·5 per cent of insoluble matter (11). By comparison, on the west coast of India the sodium chloride content of the salts used varied from 78 to 96 per cent and impurities were correspondingly high (47). Salts of marine origin no doubt contain an ample number of trace elements, which may perhaps be of nutritional interest.

2. Fermented products

In the foregoing types of product, the fermentative maturation, although essential for the attainment of the desired flavour and texture, is still a secondary consideration compared with the preservation by salt. There are, however, in Europe a few minor examples of products in which a somewhat greater degree of fermentation is the principal object of the treatment which involves only a relatively small amount of salt. Thus, "rakørret" in Norway is slightly salted trout, packed in small barrels and allowed to autolyse at temperatures close to 0°C (32°F) (68). Both fish and brine contain free acids formed by autolysis which, it is suggested, help to check bacterial development. Similarly, "surströmming" is a Swedish fermented product made from small herring preserved in brine (69).

Outside South-East Asia there is today little that resembles the completely autolysed and liquefied fish sauces such as "nuoc mam" and similar fermented fish products (dealt with in a subsequent paper by Dr. K. Amano). These result from salting fish, chiefly by method (iii), in climates where the heat induces pronounced autolytic changes during and after the penetration of salt. However, on the Mediterranean coast in classical times a similar product called "garum" was produced from fish viscera exposed to the heat of the sun in jars (24). In Greece "garos" is still the term used for various fermented fish products, for example, salted sardines and anchovies which are kept for 3–4 months. Proteolysis results in a tenfold increase in formol titratable nitrogen, which increases to 1–1·2 per cent in the product, or about 20 per cent of the total amino nitrogen. The characteristic flavour is stated to be due to dicarboxylic amino acids, such as aspartic acid and glutamic acid (44). Creac'h (22) describes a true garum still prepared in the south of France, known as "pissala" and made from small fry. Although presumed to be completely autolysed, nothing is known of its composition or nutritive value.

A more important product from Sudan is "fessikh" made from a small fatty fish from the Nile slightly salted and packed in old petrol cans, but again nothing seems to be known about its composition or nutritive value.

3. Marinated

Marinated fish or shellfish are mild cured products prepared by using various mixtures based on salt and vinegar. Different recipes use 0·5–3·5 per cent of acetic acid, up to 6 per cent sugar, along with 3–10 per cent of salt and various spices, some of which also have bactericidal properties (34). The vinegar can be added either cold or hot, or the fish can even be boiled in vinegar, so as to cook it thoroughly; or it can be applied after frying the fish in boiling fat (as in the German "Bratmarinaden").

For the cold marinaden, preservatives such as sodium benzoate or hexamethylenetetramine are often added to delay spoilage and all these products really need cool storage. Considerable proteolysis occurs (3) as a result of the activity of visceral enzymes during the "ripening" process. At first actomyosin becomes less salt soluble, but soluble nitrogen later increases due to the breakdown of protein to amino acids, some twelve of which have been detected. White crystals of l-tyrosine sometimes become visible (81). As a result of loss of protein and water, marinated fish lose weight during storage. This loss can be as high as 40 per cent on storage for 6 months at 25°C (77°F) (57a). As far as vitamins and minerals are concerned, Tables II and III show that marinating followed by canning has no particularly adverse effect. In fact, owing to the softening of the bones by the vinegar (and the canning) the calcium content is much higher than for the original material. Table IV, however, is a reminder that there are substantial losses of protein in this type of cure. Products like these are eaten for their savoury quality, and not for their nutritive value.

4. Salted and dried

This combination is probably the commonest and most effective method of preservation throughout the world. The archetype in the North Atlantic area is dried, salted cod. Heavily salted cod, in which between 33 and 40 parts by weight of salt may be used to 100 parts of fish, usually contains 18–22 per cent of salt, corresponding to saturated brine in the residual tissue fluids, whether pickle salted or left in wet stack with solid salt. There is more variability after drying owing to variations in washing prior to press-piling, but the salt content is around 25 per cent. Again there are less heavily salted variants, such as the Gaspé cure in Canada in which only 7–8 parts of salt is used to 100 of fish and which contains about 13 per cent of salt when dried. This is admired for its special flavour, produced as a result of controlled fermentation. Very lightly salted cures may contain as little as 5·5 per cent salt and 74 per cent water (28). Considerable attention is paid to the quality of these products in the major producing countries, and often Government standards are laid down and inspection schemes instituted. Control of quality of most other salted and dried products is very variable. Philippines herring (*Sardinella* sp.), brine-salted in the round and dried in the sun for the preparation of "tuyo", should, on the recommendation of technologists, contain 8–10 per cent of salt and 25–30 per cent of water (84), but there are no regulations or inspection. Often the commercial product contains much more salt than this, as fish processors tend to oversalt in the belief that they can thereby improve stale or slightly tainted fish.

The degree of drying varies greatly from product to product. For example, the "semi-dried" prawn (*Peneus monodon*) of India, which is boiled in brine for a few minutes to facilitate shelling and then brine-salted further before drying, has a moisture content of 45 per cent with 10 per cent salt (88).

Commercially produced products in India are very variable in composition (49) and are often extremely poor in quality. In Bengal, for example, typical commercially sun-dried fish contained 12–17 per cent of moisture, 40–69 per cent of protein, 2–14·25 per cent of fat and 8–27·5 per cent of ash. Sand and mud are present as impurities, which results in a high iron content of 12–100 mg./100 g. It is noticed that decomposition starts before the moisture content is low enough to stop bacterial growth. The products are also rancid, and it is concluded that current curing processes are unsatisfactory from the standpoint of hygiene and health and should be improved.

On the West Coast of India, similarly, the ratio of salt to fish used varies from place to place, and according to size of fish. The moisture content of products varies from 20 to 50 per cent (although it is mostly between 40 and 45 per cent), and salt content between 7 and 21·5 per cent (mostly about 14 per cent) and protein between 23 and 45 per cent. Products spoil easily, tend to be either too dry or too crumbly and some are unwholesome (47, 87). It is known that spoilage is slow when the water content is 25 per cent or less (58a), but atmospheric conditions often make it impossible to obtain a standardized dried product.

Traditional curing processes nearly always involve damaging the fish, for example by cutting or pressing. This results in the mechanical release of any oil that may be present, which distributes itself over surfaces and then, as a result of the easier access of atmospheric oxygen and being so unsaturated, readily undergoes oxidative rancidity, polymerization, etc. Drying, too, causes shrinkage of fish and similar exposure of the surface layer. Although it is obvious from their dark colour and rancid odour that many traditionally dried products are sold in an advanced degree of fat oxidation, in some places (e.g. Hong Kong) this is regarded as a sign of high quality. In the case of dried, salted cod, on the other hand, any darkening is regarded as deleterious. Cupric ions activate the amino-sugar browning reaction and for this reason the use of salt containing less than 0·2 p.p.m. of copper has been recommended (29, 75).

The effect of salt as a pro-oxidant for fish oils is not clear-cut. Although salt promotes rancidity in frozen fatty fish (10), this has been regarded as possibly an indirect physical effect of increasing phase interface and not specifically pro-oxygenic (Banks, private communication). If fish is covered with saturated salt-brine, in which oxygen is practically insoluble, rancidity develops only extremely slowly. In dried, salted fish, however, the oxygen has easy access to the oil however little there is. The dietary implications of the regular consumption of oxidized lipids on the availability of vitamins A and E have been considered by Olcott.

Lipolysis also takes place during drying, even in lean fish, such as cod, which has a total lipid content of only about 0·6 per cent. Cardin and Bordeleau (14) (quoted by Lovern under Part II, Sect. 2) showed that in both heavily and Gaspé-cured cod the proportion of free fatty acid reaches 50 per cent of the total lipids before lipases are inactivated.

Various types of halophilic micro-organisms can also result in spoilage of salted cod; but these are inhibited by hard drying and especially by storage at 5°C (41°F) or below. As fish containing a saturated salt solution is in equilibrium with 76 per cent relative humidity (20), it is practically impossible to dry salt fish naturally in an atmosphere of more than about 70 per cent relative humidity. Spoilage often results from too slow drying and the absorption of moisture during storage under humid conditions.

Tables II and III suggest that there are some processing losses of B vitamins in the case of dried, salted cod, although, if allowance is made for the salt content of the product, the implied losses of riboflavin, etc., seem surprisingly low. The value for niacin is again only about half of that proposed by Chatfield (16). Regarding tropical products, early work indicated that vitamin A, thiamine and riboflavin were completely destroyed by salting and drying (86). However, Adrian (2) found that the quantities of the B vitamins retained in samples of 14 species of salted and sun-dried sea fish from Angola varied by a factor of about 10. Except for riboflavin, the average values were not much below those that might have been expected from the fresh fish. Nine amino acids were estimated and it was found that the percentage of any one of them was liable to vary by a factor of about 2 from product to product. Rats fed on a diet containing 5 per cent of dried *Caranx carangus* and *Trachurus capensis* both gained about 25 per cent more weight than ones fed with an equivalent amount of a Togoland whole, ungutted and unsalted anchovy, "abobi" (*Engraulis enchrasicholus*), dried on the beach. The ash content of the latter was 22 per cent, presumably mostly sand, but otherwise it was roughly the same in all-round composition as the Angolan specimens. Some 28 per cent of the amine nitrogen in the "abobi" was present as free amino acid, possibly as a result of the hydrolysis by visceral enzymes, as compared with 2·8 per cent for dried *Trachurus capensis*. Obviously, there are large differences in the nutritive value of West African salted and dried fish, but the causes cannot be deduced from the data.

Ferreira (30) also found that the amino acid composition of the protein does not depend on the type of salting and drying, or on the degree of drying. Semi-dried prawns from India, too, showed no appreciable changes in essential amino acids (15).

In the North Atlantic countries, natural sun-drying has declined in favour of controlled drying in mechanical dryers (21), which results in a quicker drying and a more consistent product. Such methods are to be recommended for standardized control of production of other dried fish commodities, and will probably ultimately replace sun-drying even in tropical countries. The improved products would not be expected to be greatly superior nutritionally to the natural product, except perhaps in riboflavin content, which seems to be lowered by exposure to sunlight.

5. Mild cures

(*a*) **Salted.** Lightly salted herring, eaten raw a day or two later, are popular in Norway and particularly in Holland. The protein has only just begun to coagulate and in fact even the parasitic nematodes are still alive (48). Similar types of product are current in Japan, Borneo, etc. They should all be substantially the same, nutritionally, as fresh fish.

(*b*) **Dried.** Mild cures are also made for local consumption in some parts by slightly wind-drying fish. For example, the "spelding" is a very localized product, made in North-East Scotland, from a split haddock which is lightly salted and slightly dried in the open air, thereby acquiring an attractive, delicate, "cured" flavour. It may be presumed that the nutritive value is practically unchanged from that of fresh fish.

(*c*) **Boiled in brine.** This process, which is common throughout South-East Asia, combines salting with a heat treatment resulting in partial sterilization. The product can be marketed either (i) without further treatment, merely wrapped in bamboo leaves and packed in baskets for sale; or (ii) after subsequent sun-drying, or hot-smoking.

6. Summary

It may be concluded that salting as a process, whether combined with drying or not, results in some loss of nutrients along with the brine, and that there is often a further loss of protein as a result of autolysis, which plays an essential part in developing the required flavour during ripening. There is some loss of vitamins in salting, depending on the severity of the process; the protein composition and availability can also be adversely affected. Whereas standards of composition and quality of some types of product are very strict, in most cases there is no effective control and great variability in palatability as a result.

III. SMOKED FISH

1. Smoked alone

An example of fish smoked without salting, or separate drying, is the hot-smoked (and thereby cooked) "bonga" of West Africa. There are various grades of quality, depending on the degree of smoking, and the frequency of resmoking required to maintain edibility prior to eventual sale. The least smoked and dried is regarded as the best. Such a process must be quite common under primitive conditions, particularly on a domestic scale, but no data of nutritional interest seem to have been recorded.

2. Salted and smoked

The "red herring" is an example of cold-smoking a heavily salted, ungutted product (23). It is smoked for a week, losing a total of 20–25 per cent of its original weight. The final salt content is about 14 per cent. Formerly, a hot-smoked herring seems to have been current—a longer-keeping ancestor of present-day "Bückling" (54), and there must be many similar types of product made in hot countries.

Spoilage by moulds rather than bacteria is a problem with this type of product.

Proximate analyses are available for products such as red herring (71), and various tropical cures (11a); but little extra is known about the effect of the smoking on nutritive value, additional to the effect of salting by itself, already dealt with.

Various combinations of all three processes of salting, smoking and sun-drying also occur, in various orders. For example, Johnson (39) made an acceptable cure in Ghana by brining the fish for 18 hours, sun-drying for 3 days and then smoking at 60°C (140°F) for a day, until the water content was 25 per cent and the salt content 9 per cent.

3. Mild cures

Fish can be cold-smoked (at a temperature insufficient to coagulate the protein) and subsequently eaten cooked (as with kippered herring) or raw (as with smoked salmon), or hot-smoked, as with the German "Bückling", Russian "Salaka" (51) and smoked flatfish and eel. These products are all very savoury and palatable if consumed whilst still fresh.

The decrease in weight due to the evaporation of water (a technological loss) during mild smoking can be from 5 to 25 per cent of the weight of the fish. The salt content is usually between 2 and 3 per cent (23, 70) (although occasionally it can be as excessively high as 8 per cent); but in smoked salmon it is normally between 3 and 6 per cent in various parts of the same fish (36). In some types of product, smoking is so slight that the fish is scarcely even coloured by the smoke.

The amounts of smoking and drying undergone by the fish in the manufacture of a particular product are also subject to considerable variation in the traditional process; so that, unless controlled mechanical methods of production and quality control are applied, the keeping quality tends to be rather variable and the reliability of the product is thereby decreased. However, in this case such improved methods should not alter the nutritive value of the product to any significant extent.

A variant from the Philippines, "tinapa", is made from

Sardinella sp. by boiling in brine for a few minutes, followed by hot smoking, so that the product contains 5–15 per cent of salt and 55–60 per cent of water (84).

Loss of solids in the concentrated cold brine dip by solution of protein, etc., can amount to about 1 per cent of the weight of the fish in the case of cod fillets (Aitken, unpublished).

The proteins of lightly-smoked fish are said to be as easily digestible as those of unsmoked cooked fish. Early work (53) showed that there was no appreciable loss in the small amounts of vitamins A and D in herring flesh during smoking and subsequent canning. Junker (42) also found no destruction of vitamin A. Some isolated results for haddock and herring suggested that there was some loss of thiamine in smoking, but the values were low in any case. More recent data of Hoogland (35) on cod and haddock, and Klocke *et al.* (46) on freshwater herring (*Leucichthus artedi*) and sucker (*Catostomidae* sp.) from Lake Michigan (nearly 75 per cent retention of niacin), taken with the analyses of Taarland *et al.* (79) show fairly conclusively that there is no appreciable loss of B vitamins in mild smoking, hot or cold, even when followed by subsequent canning of the product (see Table III).

4. Summary

To sum up the effect of smoking, it is to be expected that hard salted and dried, smoked fish will show losses of B vitamins and protein value associated with these processes. However, mildly smoked fish is not detectably less nutritious than fresh, unprocessed fish. Again, the lack of standards of quality hinders increased consumption.

IV. CONCLUSIONS AND DISCUSSION

(1) Analyses of cured fish are far fewer than those of fresh fish and very few enable the nutritive effects of a given process to be assessed, because there is often no direct comparison of fish before and after curing. The methods of determining nutritive quality (for example, amino acid composition) are not always free from uncertainty and some vitamins are notably difficult to extract quantitatively from dry material. The conclusions drawn from data are sometimes unjustified. Abstracts can be misleading and even erroneous.

(2) From the limited published evidence available it would appear to be justifiable to conclude that the processes of drying, salting and smoking, in themselves, do not have a very deleterious effect on the nutritive quality of fish. Hard, traditional curing for long-term preservation, as might be expected, appears to have a greater effect than mild, smoke curing for example, the products of which are little different, nutritionally, from fresh fish, which they also resemble in keeping quality.

Processing losses, which include the escape of and the damage to nutrients, although not negligible can nevertheless be regarded as relatively small. For example, some 90 per cent of the vitamin assays for the whole range of cured products presented in Table III indicate that more than 50 per cent of the original vitamin is retained in the product. In the main there appears to be no great reduction in the digestibility of the protein in cured fish, but a range of 0–40 per cent reduction in Pepsin Digest Residue index has been reported. In addition, 75–85 per cent retentions of amino acid are quoted for some dried products.

(3) The loss of water, a technological loss inherent in most processes, naturally results in an apparent increase in the concentration of nutritionally important constituents, and represents an increase in nutritional value for weight purchased. The bulk of evidence presented indicates that the most important nutritive effects of drying, salting and smoking are the losses of edible flesh and nutrients, which take place during trimming, during handling due to accidental loss, and during curing. Deterioration of edible material and losses due to pest infestation during the subsequent storage of products should also be considered to be of significance nutritionally. These losses, apart from trimming and accidental losses, which may be utilized at considerable nutritive loss in fish meal production and animal feeding, are not normally recoverable. As hard cured fish must be considered primarily as a means of storing high grade protein, the vitamins and minerals, it is suggested, being only of minor importance, these losses, which determine nutritive quantity, should be studied closely.

(4) Although new methods of dehydration (such as freeze-drying, which is commercially in its infancy, primarily for foodstuffs other than fish) result in little change in the nutritive value, the acceptance of the products, when rehydrated as fresh fish, is somewhat qualified by textural changes.

(5) Although the dearth of data about the nutritive value of cured fish has resulted in existing food tables being unsatisfactory, nutritive value is only one aspect of quality, and although more data of this nature are highly desirable, priority should be given to acquiring data on yields, losses and quality as understood by food technologists. It is more important from the nutritional standpoint to ensure that all the fish that can be caught is processed, to give the maximum yield of a satisfactory product that people will want to eat. Many commercially available products are of inferior and variable quality. These could be improved, with a view to supplying the maximum amount of protein in the best possible way, by the application of the technical knowledge that is already available immediately, without awaiting further nutritional data.

(6) It must be recognized that there are cases at present where the fish that is cured is too spoiled to be used for other purposes, and that, in fact, curing can be a useful outlet for such fish. This attitude can have an adverse effect throughout an industry. Although it is true that dark, rancid, oxidized, spoiled, sandy and insect-infested

products are marketed and even relished in many parts, this may not be so for much longer. As developing countries become industrialized and transport and standards of living improve, they are liable to repeat the pattern of development of Western Europe and North America in preferring milder cures. Despite conservativism, less intense flavours should come to be preferred as fish becomes cheaper and more plentiful, so that it can be used as a source of protein instead of as a condiment. With such an increasing world trend towards less heavily cured fish, the problem of the nutritional losses of hard cures will gradually become insignificant.

(7) In the transition period, curing will continue to play a part in world nutrition for many years. But if the maximum use is to be made of this source, quality must be improved and standardized. The methods applicable in a cottage industry need to be rationalized for mass production, if the output is to be of satisfactory quality and consistency. This can be effected only through the operation of quality control and inspection, for example by Government organizations, with the necessary technical knowledge to formulate and implement specifications and standards of product and process.

(8) Mild cured products also require standards, control and inspection, particularly if adopted in warm climates, and methods of production and distribution defined so as to prevent the marketing of grossly deteriorated products of poor eating quality.

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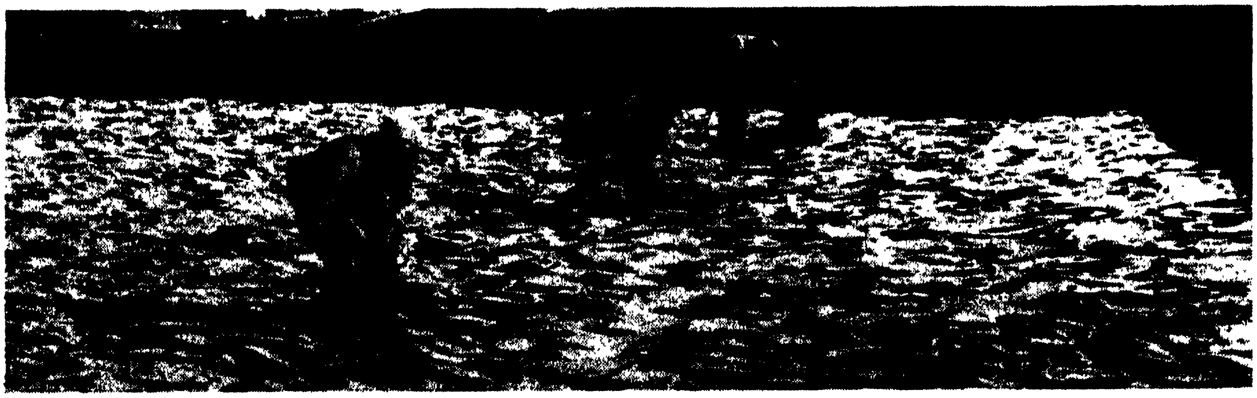

Newfoundlanders at work drying and salting cod—"making fish" as they call it.

THE INFLUENCE OF FERMENTATION ON THE NUTRITIVE VALUE OF FISH WITH SPECIAL REFERENCE TO FERMENTED FISH PRODUCTS OF SOUTH-EAST ASIA

by

K. AMANO

Fermented fish pastes and sauces are eaten in the protein-deficient Far East as condiments to relieve the monotonous rice diet. Individual daily consumption is not great, but use is virtually universal, and nutritional return is significant. The author examines how various fermentation processes change nutritive value. Products manufactured under about 60 names are grouped for examination according to their principal fermenting agent. Two groups of traditional products are discussed as well as non-traditional products manufactured by chemical hydrolysis, acid ensilage, and a new "quick" method.

The author found nitrogen loss during fermentation of traditional products averaged about 30 per cent. Amino acid retention seemed fairly good. Fermented fish oil had little nutritional value, due to developing rancidity. Nutritional significance of B vitamins was judged minor.

Three proposals to hasten fermentation are discussed. The author finds no reported cases of serious poisoning from product consumption. He finds reasonable assurance of nutritional value in each product and urges establishment of quality control.

INFLUENCE DE LA FERMENTATION SUR LA VALEUR NUTRITIVE DU POISSON, NOTAMMENT POUR LES PRODUITS FERMENTES DU POISSON DANS LE SUD-EST ASIATIQUE

Les pâtes et sauces de poisson fermenté sont consommées dans l'Extrême-Orient, déficitaire en protéines, comme condiments pour relever le régime monotone du riz. Leur consommation journalière par individu n'est pas grande, mais leur usage est pratiquement universel, et leur avantage en alimentation significatif. L'auteur examine comment les divers procédés de fermentation peuvent modifier la valeur nutritive. Il a groupé des produits fabriqués sous 60 noms divers à peu près, pour les étudier en fonction du principal agent de fermentation. Il examine deux groupes de produits traditionnels, ainsi que des produits non traditionnels, fabriqués par hydrolyse chimique, par ensilage sous acide et par une nouvelle méthode rapide.

L'auteur a trouvé que la perte d'azote durant la fermentation des produits traditionnels se situait à une moyenne de 30% environ. La rétention des acides aminés semble assez bonne. L'huile de poisson fermenté a peu de valeur nutritive par suite du développement du rancissement. La signification nutritionnelle des vitamines B a été considérée comme secondaire.

Trois propositions destinées à accélérer la fermentation sont examinées. L'auteur n'a découvert aucun cas signalé d'empoisonnement sérieux par la consommation du produit. Il a trouvé pour chaque produit une assurance raisonnable quant à sa valeur nutritive, et il souligne l'urgence d'un contrôle de qualité.

EFECTO DE LA FERMENTACION EN EL VALOR NUTRITIVO DEL PESCADO, CON ESPECIAL REFERENCIA A LOS PRODUCTOS PESQUEROS FERMENTADOS DE ASIA SUDORIENTAL

Las pastas y salsas de pescado fermentado se consumen en las regiones del Extremo Oriente en las que escasean las proteínas para aliviar la monotonía de una alimentación a base de arroz. El consumo diario individual no es grande, pero el empleo de estos productos es virtualmente universal y su importancia nutritiva de significación. El autor examina la manera en que varios procesos de fermentación cambian el valor nutritivo. Los productos manufacturados bajo unos 60 nombres distintos se agrupan para examinarlos según su principal agente de fermentación. Se estudian 2 grupos de productos tradicionales, así como productos no tradicionales preparados por hidrólisis química ensilado ácido y un nuevo método "rápido".

El autor ha comprobado que la pérdida de nitrógeno durante la fermentación de los productos tradicionales es, por término medio, de un 30%. La retención de aminoácidos parece ser bastante buena. El aceite de pescado fermentado tiene escaso valor nutritivo debido a la aparición de rancidez. La importancia nutritiva de las vitaminas B se juzga de poco valor.

Se examinan 3 propuestas para acelerar la fermentación. El autor no encuentra noticias de casos de envenenamientos graves por consumir estos productos. En todos ellos determina un valor nutritivo bastante razonable e insta a que se establezca un control de la calidad.

THE daily diet of the protein-deficient Far East is closely linked with fermented fish products. Fish pastes and sauces are used as condiments to brighten monotonous rice dishes. No one eats a great daily volume of these products, but almost everyone consumes a little bit every day.

The nutritive return is significant. For example, 40 g. per person per day of a Vietnamese fish sauce accounts for 7·5 per cent of an individual's total nitrogen intake.

Flavour is of first importance, and South-east Asians are connoisseurs of these products. Both flavour and nutritive value depend on the fermentation process. Fermentation is also an important factor in preserving and shipping fish in these hot, damp countries, particularly for handling surpluses from large seasonal catches.

Fish pastes, sauces and miscellaneous fermented fish are manufactured under about 60 names in South-east Asia. "Fermented fish product" is rather ambiguous, since dried or salted fish may become fermented in time.

The term "fermented fish product" is defined and discussed here as a type of processed fish obtained by maceration (or hydrolysation) by introducing microbial action in the process, normally in the presence of salt.

The object of this paper is to examine how fermentation processes change the nutritive value of these products.

The variety of products will be grouped into three main categories. Categories will depend on the principal fermenting agent. Each agent has a different effect on the natural nutritional level of the fish.

The proposed groups are:

(I) Traditional products, mainly fermented by the action of enzymes in fish flesh and entrails, in the presence of salt.

(II) Traditional products, fermented by combined effects of fish enzymes and microbial enzyme, microbial enzyme prepared and added as a starter in addition to salt.

(III) Non-traditional products manufactured by acceleration of fermentation, acid ensilage and chemical hydrolysis.

For group (I) products, use of entrails seem significant for manufacture. This is because digestive system enzymes disintegrate fish protein faster than flesh enzymes. Some kinds of fish seem to have comparatively high-powered enzyme action, suggesting they are more suitable for fermented products.

Also in these products the addition of salt may help stop bacterial decomposition during processing, but less salt means rapid formation of amino acid. It also means greater loss of ammonia nitrogen. Minimum salt concentration to keep down ammonia formation should be 20 per cent of product weight, the usual commercial proportion used. As always, purer salt means quicker hydrolysis.

Some variety of bacteria may be indispensable for flavour in these group (I) products; but halophilic microorganisms surviving in fermented fish tend to produce ammonia rather than amino acids.

The little information about group (II) products seems to suggest the major fermenting agent is lactic acid with fermentation developing in the mixed cereals. The amount of lactic acid formed in one product was as high as 7 per cent on a moisture-free basis. However, the significance of the fish enzymes cannot be ignored.

In fish paste preparation, incorporation of the mould, *Aspergillus oryzae*, was found promising. It may complete fermentation in a shorter time. Fungal action in commercial preparation of Katsuobushi was noticeably important.

During fermentation in both group (I) and group (II) products, nitrogen loss averaged about 30 per cent. It may be smaller in fish sauce, because the process involves less drainage. In both sauce and paste, amino acid retention was fairly good, but there is not enough information on this.

Fermented fish oil is of little nutritional value because of developing rancidity. The nutritional significance of B vitamins in the products was minor.

Further research is needed before proposals to hasten fermentation can be applied. Such proposals discussed here are: temperature rises, use of enriched enzyme and combination with chemical hydrolysis.

No serious cases of fermented fish poisoning have been reported. But there have been sporadic outbreaks of botulism type E from Izushi, the Japanese home-made fermented fish in group (II).

The nutritional value of each product is reasonably assured. However, it is stressed that quality control should be established.

For general aspects of fermented fish, the reader is referred to papers by van Veen and Westenberg (44, 47, 48). An excellent review by Ngo-Ba-Thanh (28) deals particularly with Nuoc-mam. The Fisheries Products Manual, edited by Subba Rao (37), offers more detailed description of the individual products in South-east Asia.

GROUP I: TRADITIONAL PRODUCTS, MAINLY FERMENTED BY THE ACTION OF ENZYMES IN FISH FLESH AND ENTRAILS IN THE PRESENCE OF SALT

A number of fermented products abundantly produced in the South-east Asian countries belong to this group. Ngapi (Burma), Shidal Sutki (India), Shiokara (Japan), Belandran (Malaya), Bagoong, Patis (Philippines), Trassi (Sumatra), Kapi, Nan-Pra (Thailand) and Nuoc-mam (Vietnam) are the main items.

1. Proteolytic enzyme in raw fish related to fermentation

These products are mostly prepared by heavy salting to avoid activity of spoilage bacteria. Therefore, in the presence of large amounts of salt, the activity of proteolytic enzyme becomes more significant for the hydrolysation of fish.

The proteolytic activity of the fish enzymes is not, however, necessarily high, and a fairly long time is required to finish the process.

Partmann (31) investigated proteolysis progressed in the homogenates and block meat of tench muscle during storage at 0° to 20°C by using toluene as antiseptic. It was found that during storage at 0°C for over 2 months, little increase in basic nitrogen and amino nitrogen (about 20–30 per cent increase) occurred. Also, during storage at 20°C, a significant increase in tyrosine nitrogen occurred after 1 to 2 months.

(i) **Enzyme activity and species of fish.** The potential of proteolytic enzyme seems to vary with fish species. Ground fish, such as haddock, have less activity of proteolysis than pelagic types like mackerel or anchovy. Chesley (4) examined the correlation between enzyme activity and movement of fish in varieties such as mackerel, menhaden, scup, sea robin, puffer and toad fish. He reported higher activity in fish with greater movement.

From findings described by Pidlaoan (32), species such as slipmouth, goatfish and lizard fish are not rich in proteolytic enzyme, because they indicated poor development of hydrolysation even after 6 months' storage under tropical temperature.

(ii) **Enzyme activity and bodily portion of fish.** Activity level of protein-splitting enzyme differs with the portion of the fish. In general, the enzyme is more active in the digestive system than in muscle tissues. Fujii *et al.* (8) pointed out that in sardine (*Sardinella melanosticta*) pyloric caeca was found to have higher proteolytic activity than stomach. The flesh portion indicated the least potency. In terms of the amount of amino nitrogen generated after 65 hours' storage at 35°C from 2 ml. of 5 per cent neutral casein solution by the action of slurries prepared from different portion of sardine, pyloric caeca gave 3·88 mg., while stomach and muscle gave 2·28 mg. and 1·39 mg. respectively. These workers observed a certain degree of proteolytic enzyme even in sardine muscle tissues. Sardine is used and highly prized by manufacturers of fermented fish in the region. Rosé (33) tested glycerin extract of various portions of fish for liquefaction of gelatine, and reported that the activity of viscera was twice as high as whole fish, while muscle extract gave none of the activity.

According to Luijpen (19), trypsin in the pyloric caeca taken from freshly caught herring substantially contributed to endopeptidase activity. In the stomach of herring, it contained considerable pepsin; but pepsin activity should have little importance in the pH range of the brine normally used for Maatjes herring. Cathepsin was almost negligible in herring liver and muscle. He mentioned that the presence of pyloric caeca is necessary for the development of the Maatjes flavour.

Croston (5) also examined tryptic enzyme of pyloric caeca from chinook salmon, and activities were found with properties similar to mammalian trypsin and chymotrypsin; but the fish enzymes were inactivated in acidic solutions in which mammalian enzymes are stable. The optimal pH for proteolysis by the mixed fish enzymes was pH 9·0 and the optimal temperature was 49°C.

(iii) **Enzyme activity and fishing season.** There may be a possibility of change in enzymatic activity of certain species of fish according to its fishing season. Kashiwada (16) reported a difference in proteolytic strength of pyloric caeca from skipjack caught in different fishing seasons. As to the skipjack caught by pole line in waters near Japan, the potency of proteolytic enzyme reaches maximum in April and lowers from June to August. It recovers again in winter. It is interesting that April is the month of the year when the abundant catch of skipjack is normally expected. The coincidence between the best fishing season and the period of high level of proteolytic enzyme in pyloric caeca may be reasonably presumed, since the fishing is entirely dependent on hook and line method.

A similar observation was reported by Ananichev (1) on the activities of pepsin, trypsin, amylase and lipase of the burbot, pike, perch and bream from the Rybinsk reservoir. Maximum activities of pepsin, trypsin and lipase was found to coincide with periods of intense food intake during the winter months for burbot and during summer for pike, perch and bream.

(iv) **The rôle of the fish enzymes in fermentation.** The fermentation process under this category is mainly carried out by proteolytic enzyme in flesh and entrails of raw fish, though bacterial participation cannot be ignored. A comparative study done by Shimidu (35) on chemical changes in nitrogen forms of "Katsuo-Shiokara" (fermented skipjack entrails) indicated that enzyme inherent in the fish was likely to be dominant in the action of splitting protein in the raw materials during 3 months of storage (Table I). In the whole heat-processed sample, no increase was found in the amount of nitrogen soluble in hot water, while the sample with added toluene showed increase in both soluble nitrogen and monoamino nitrogen. This was similarly observed in a control sample which represented the commercially processed product. This fact may indicate the necessity of fish enzymes in the fermentation process of this group (Table I).

2. Significant rôle of salt

The rôle of salt is highly significant to guarantee the quality of the finished products in this category. The addition of salt can be undoubtedly interpreted as a preservative which keeps raw fish from bacterial spoilage. The autolytic change in fish is expected to continue during storage time.

Therefore, in these types of products, salt concentration becomes most important at the very beginning of fermentation, since an inadequate amount of salt may induce undesirable effects on the product. Sometimes the

TABLE I

Effect of antiseptic and heat-processing on changes in nitrogen compounds in "Katsuo-Shiokara" during storage for 3 months

(Shimidu, 1934)

	Control			*Toluene added*			*Heat-processed*		
Storage time month	0	1	3	0	1	3	0	1	3
Moisture	65·12	—	—	65·12	—	—	65·12	—	—
NaCl	14·85	—	—	14·85	—	—	14·85		
Total nitrogen	2·32	—	—	2·32	—	—	2·32	—	—
Heat-coagulable nitrogen	0·35	0·13	0·08	0·35	0·15	0·11	0·35	0·53	0·56
Hot water soluble nitrogen	1·97	2·19	2·24	1·97	2·16	2·21	1·97	1·79	1·76
Monoamino nitrogen	0·66	1·19	0·94	0·66	0·93	0·92	0·66	0·44	0·39
Ammonia nitrogen	0·039	0·164	0·213	0·039	0·124	0·138	0·039	0·065	0·163

amount of salt can be reduced if such a process as drying is adequately combined in the fermentation, or if the temperature of the material can be maintained at a comparatively low range.

(i) **Concentration of salt used in commercial products.** Proportion of salt to fish varies largely from one product to another. For fish sauce, the process is simple. It consists of mixing wet fish and salt in the proportion of 1 : 2 or 1 : 3, and allowing the mixture to ferment under anaerobic conditions for periods from 3 months to a year. A similar process is being used for fish paste, such as Bagoong in the Philippines. The amount of salt generally used for these products in South-east Asia is enough to saturate the moisture contained in the fish. As most wet fish contain about 80 per cent moisture, 1 part salt to 3·5 parts fish by weight will furnish a product with only a slight excess of salt.

There are some fish pastes whose salt content has been reduced by drying. Examples are Man-tom (Annam) and Pra-hoc (Cambodia). Possibly, the saturation of salt may be attained in these products by drying, even when the addition of salt is in a low range of 10 : 1.

(ii) **Effect of salt concentration on the maceration of the product.** Since the flavour problem of these products is considered as primarily important, chemical changes in nitrogenous compounds have been extensively worked out, particularly with reference to the quantity of salt employed. Rosé (33) demonstrated relation between the proportion of salt to fish and the amounts of nitrogen compounds transferred to Nuoc-mam, and noticed that traditional use of salt was safe to retain the nitrogen compounds available for human nutrition (Table II).

From Rosé's earlier findings, it will be obvious that a recommendable proportion of salt to fish is not less than 1 : 4 (20 per cent salt in the mixture).

Shimidu (34) made a more detailed examination on the fermented entrails of skipjack, "Katsuo-Shiokara". Addition of 20 per cent of NaCl to the raw material should be necessary for maintaining quality. In his sample containing 10 per cent NaCl, monoamino N reached a level of 1,000 mg. per cent after a month's maceration, but it dropped to 930 mg. per cent after 3 months. The product containing 20 per cent NaCl was still showing increase of monoamino N, even after 3 months. A tremendous development of ammonia was observed in the sample with 10 per cent NaCl: 400 mg. per cent after a month and nearly 500 mg. per cent after 3 months' storage, while 150 mg. per cent of ammonia in the sample with 20 per cent NaCl was seen after the same storage period (Table III).

TABLE II

Amount of nitrogen compounds in Nuoc-mam with different NaCl content after 33 days' maceration

Proportion of salt to fish	1 : 3[1]	1 : 4	1 : 6	1 : 12	1 : 40
Total nitrogen (g./l.)	17·3	23·1	26·3	28·9	31·3
In 100% of total nitrogen					
Organic-N %	91	90·3	76·0	68·9	49·3
Amino-N %	39·4	39·5	38·5	32·3	20·7
Ammonia-N %	9	9·7	24·0	31·1	50·7

[1] Proportion traditionally used in the Nuoc-mam processing (Rosé, 1918; (Ngo-Ba-Thanh, 1953)).

TABLE III

Changes in various nitrogen compounds of "Katsuo-Shiokara" with different NaCl content during 3 months' storage under atmospheric temperature (%)

(Shimidu, 1934)

Concentration of NaCl	*20% NaCl*			*15% NaCl*			*10% NaCl*		
Storage time	0	1	3	0	1	3	0	1	3
Moisture	61·29	—	—	65·12	—	—	68·95	—	—
Total nitrogen	2·18	—	—	2·32	—	—	2·46	—	—
Heat coagulable N	0·33	0·18	0·10	0·35	0	0	0·37	0·07	0·03
Hot water soluble N	1·85	2·01	2·08	1·97	2·38	2·35	2·09	2·39	2·43
Nitrogen form ppted with $Cu(OH)_1$	0·14	0·13	0·16	0·15	0·15	0·24	0·16	0·17	0·20
N form ppted with tannic acid	0·24	0·19	0·19	0·25	0·21	0·26	0·26	0·16	0·16
N form ppted with tungstic acid	0·94	0·83	0·89	0·99	0·86	0·94	1·05	0·86	0·99
N form ppted with phosphotungstic acid	1·07	0·97	1·07	1·13	1·10	1·33	1·20	1·23	1·34
Monoamino N	0·62	0·81	0·83	0·66	0·98	0·87	0·69	1·02	0·93
Ammonia N	0·037	0·110	0·147	0·039	0·193	0·349	0·041	0·402	0·493

A similar observation was reported by Nagasaki and Yamamoto (26, 27) on "Ika-shiokara", a fermented product prepared from squid flesh. Addition of 10 per cent salt to wet squid meat seemed to be favourable for a rapid increase in monoamino acid during the first 30–40 days' storage, but a large production of ammonia was inevitable. The decrease in amino nitrogen occuring after a month's storage at 30°C could be substantially arrested by mixing more than 20 per cent salt in the raw flesh.

As to effective retention of nitrogen compounds directly available for human nutrition, these works have shown fairly consistently that the minimum amount of salt should not be lower than 20 per cent of the wet fish, when the product is prepared under tropical conditions. The salt content of commercially prepared products is considered to meet this minimum requirement.

(iii) **Effect of salt impurities on maceration of fish.** Salt impurities such as magnesium and calcium have been regarded as causing delay of salt penetration into fish. A series of works done by Hamm and Clague (11) confirmed that salt impurities also delay the maceration of Bagoong, a fish paste widely produced in the Philippines. The objectionable impurities reached as much as 1·36 per cent calcium sulfate, 3·9 per cent magnesium sulfate and 2·7 per cent magnesium chloride (Table IV).

TABLE IV

Protein content of liquid portion of anchovy Bagoong processed with salt of different purity and stored in 1-gallon glass jars

(Hamm and Clague, 1950)

Sample	*Storage temperature*	*Protein content after storage period of:* 1 day	7 days	14 days	21 days
California salt	Room temperature	4·03	5·57	6·40	7·12
California salt	37°C	4·27	6·91	8·58	9·42
Manila salt	Room temperature	3·74	4·82	5·72	6·43
Manila salt	37°C	3·89	6·15	7·19	8·41

(iv) **Time required for the maceration.** One factor prohibiting the development of fermented fish production in South-east Asia is the long period required to macerate the products. The retardation of fermentation is undoubtedly due to the use of large concentrations of salt.

For fish sauce and paste products, 6 months to a year is common to complete the ripening. Work reported by Rosé indicated 3 months' maceration was not enough to get normal product yield in terms of total nitrogen. This was with a Nuoc-mam preparation and the traditional way of adding salt.

Storage prolonged more than 6 months also adversely affected the retention of amino nitrogen.

Therefore, in the case of Nuoc-mam, the product should be matured from 4 to 5 months to be most desirable for nutrition.

3. Deterioration of fermented fish during maceration

(i) **Ammonia formation by non-bacterial action.** Although fermented fish products of group (I) contain much salt, certain kinds of deterioration are unavoidable, such as ammonia formation.

Ammonia, however, may have two different origins. One is from the activity of the enzymes in fish; the other is bacterial. Yamada (46) observed little practical effect on the phosphorylation process in which enzymatic ammonia formation was involved. In the muscle tissue of freshly caught sardine, ammonia content reached 30 mg. per cent level within 7 hours in the presence of 15 per cent NaCl.

In the case of entrails, ammonia formation not caused by bacteria also occurs. In a storage test of skipjack in which pyloric caeca were kept aseptically under toluene and thymol at 40°C for 18 days, Kashiwada (17) observed a steady increase in ammonia (Table V).

TABLE V

Changes of nitrogen distribution in skipjack pyloric caeca during autolytic progress

(Kashiwada, 1956)

Time of storage	*Water-soluble N*	*Ammonia N*	*Monoamino N*	*Diamino N*
	%	%	%	%
0	2·02	88	0·71	0·32
3	2·14	95	0·95	0·35
7	2·15	110	1·03	0·33
12	2·15	111	1·05	0·36
18	2·15	111	1·08	0·37

Storage temp., 40°C, toluene 3%, thymol 0·2% are incorporated.

By using enzyme preparation from pyloric caeca, he examined the possibility of precursors on adenine, guanine, asparagine, glutamine, arginine, histidine and urea. None of these were found to generate ammonia. Certain compounds in the material, which can be precipitated by lead acetate, could be the precursor.

(ii) **Bacterial growth during maceration.** According to Hamm and Clague (11), bacterial count of anchovy Bagoong was found quite low even after a week's storage. A Bagoong prepared with Manila salt showed an initial count of 3,500,000 and 58,000 after 7 days, and only 100 per g. of the Bagoong after 56 days at room temperature. Therefore, there seems little evidence to account for bacterial effect on both "maturing" and deterioration of the Bagoong (Table VI).

TABLE VI

Bacterial plate count of anchovy Bagoong stored in 1-gallon glass containers

(Hamm and Clague, 1950)

Treatment	*Storage temperature*	*Initial*	*Bacteria per gram after storage period of:* 3 days	7 days	14 days	21 days	56 days[1]
Unsalted		6,500,000	—	—	—	—	—
California salt . . .	R.T.	2,900,000	—	46,000	5,400	320	80
California salt . . .	37°C	—	—	15,000	1,800	110	80
California salt . . .	45°C	—	15	—	0	2	60
Manila salt	R.T.	3,500,000	—	58,000	6,200	350	100
Manila salt	37°C	—	—	16,000	3,200	150	100
Manila salt	45°C	—	16	—	2	5	80

[1] Samples were stored at room temperature (R.T.) after 4 weeks; anchovies were salted with 1 part salt to 3·5 parts by weight of ground fish.

TABLE VII

Changes in bacterial count in "Ika-Shiokara" during ripening period at 20°C bacterial number/ml. of the pickle

(Nago, 1951)

Days of storage	*1*	*8*	*12*	*16*	*19*	*23*	*26*	*33*	*41*
Subculture at 25°C .	9×10^4	$2{\cdot}7 \times 10^6$	$1{\cdot}7 \times 10^6$	$2{\cdot}1 \times 10^6$	$1{\cdot}8 \times 10^7$	$4{\cdot}4 \times 10^7$	$6{\cdot}5 \times 10^7$	$4{\cdot}7 \times 10^7$	$3{\cdot}2 \times 10^7$
Subculture at 35°C .	9×10^4	$2{\cdot}2 \times 10^6$	$1{\cdot}3 \times 10^6$	$1{\cdot}9 \times 10^6$	$1{\cdot}6 \times 10^7$	$2{\cdot}3 \times 10^7$	$5{\cdot}2 \times 10^7$	$5{\cdot}2 \times 10^7$	$3{\cdot}7 \times 10^7$

Nagao (25) made bacteriological examinations of "Ika-shiokara", experimentally prepared, but in a fashion almost identical with commercial production, during a period of 41 days' storage at 20°C. Bacterial count changed from original 90,000 to 32,000,000 per g. in 41 days. Nagao suspected the possibility of a bacterial rôle in the ripening of "Shiokara", particularly in the later part of fermentation (Table VII).

Nagao and Kimura (24) also made identification of bacteria isolated from "Ika-shiokara", containing 20 per cent NaCl, and described *3 Bacillus* spp., *4 Micrococcus* spp. and a *Lactobacillus* sp. Most strains were less salt-tolerant, except *Micrococus flavus*, which showed growth in a medium containing 10 per cent NaCl. During the course of fermentation, *Bacillus mycoides*, *Bacillus subtilis*, *Bacillus mesentericus fuscus*, *Micrococcus subflavescens*, and *Lactobacillus* sp. appeared in the product up to 5 days, and *Micrococcus subflavus*, *Micrococcus freudenreichii*, and *Micrococcus perflavus* were detected after 8 days' storage; while four *Micrococci* (*subflavescens*, *freudenreichii*, *flavus*, and *perflavus*) were dominant after 20 days. No halophilic organism, which could grow on the medium with 20 per cent NaCl, was isolated from the product.

Zenitani (50) examined aerobic bacteria in some "Shiokara" products, commercially prepared from squid, skipjack, yellow tail, mackerel and sea urchin, and found that the most frequently isolated species were *Bacillus subtilis* and *Micrococcus varians*. He reported *7 Micrococci*, *6 Bacilli*, *3 Vibrios*, *Achromobacter* and *Flavobacterium*. Bacterial counts showed some variations: from $1{\cdot}5 \times 10^3$ to $2{\cdot}3 \times 10^5$ per g. for skipjack "Shiokara", and from $3{\cdot}6 \times 10^6$ to $2{\cdot}4 \times 10^7$ for squid "Shiokara"; but storage times from the beginning of preparation for these products were not given.

With regard to salt-tolerance, *Bacillus* showed good growth at NaCl concentration of 5 per cent, whereas *Vibrio*, *Achromobacter*, *Flavobacterium*, and *Microccus* indicated their best growth at 10 to 20 per cent NaCl.

Concerning the capability of forming amino acids from squid flesh, no appreciable difference was observed in these bacteria. However, formation of ammonia differed markedly with the species. *Vibrio*, and the majority of *Micrococci* were able to produce much more ammonia than *Bacillus*; and *Achromobacter* was also able to form ammonia to a large extent (Table VIII).

Consequently, ammonia production during "ripening" process of "Shiokara" could be caused by the growth of these bacteria, which resist rather high salt tensions, although they may possibly contribute to the addition of amino nitrogen to some degree.

TABLE VIII

Formation of amino-nitrogen and volatile basic nitrogen from squid flesh by "Shiokara" bacteria

(Zenitani, 1955)

	pH	*Volatile base N*	*Amino N*	*Soluble total N*
Vibrio marinopraesens .	7·0	52·1	91·0	188
V. aquatilis . . .	7·2	56·0	64·7	132
Micrococcus aurantiacus	6·3	17·2	62·4	182
M. sp.	6·8	26·4	51·2	156
M. citreus . . .	6·9	28·0	64·4	168
M. flavus . . .	6·5	8·0	58·4	160
M. epidermidis . .	6·9	26·4	54·4	156
M. conglomeratus .	6·4	10·8	61·5	168
M. varians . . .	6·2	12·4	60·0	172
Achromobacter sp. .	7·2	24·8	63·5	140
Flavobacterium malinum	6·0	6·4	61·2	180
Bacillus subtilis . .	6·0	5·6	64·7	164
B. pumilus . . .	6·0	6·0	61·2	169
B. circulans. . .	6·0	6·4	59·5	176
B. brevis . . .	6·2	7·2	55·6	156
B. laterosporus . .	6·2	4·8	61·2	180
Control . . .	6·0	6·6	61·9	172

(iii) **Bacteria contributing the flavour to the fermented fish products.** Certain bacteria strains have been regarded as essential to give a particular flavour to fermented fish products. Work on Nuoc-mam by Boez and Guillerm (3) indicated that a strict anaerobe isolated from Nuoc-mam preparation was indispensable to make up the specific flavour of the product. This anaerobe could grow only in fish flesh, not entrails. It was supposed to be a *Clostridium*, which was highly proteolytic with optimum growth temperature between 28 and 45°C.

Two types of anaerobes were also regarded as being the cause of the characteristic sweet odour of Colombo-cured mackerel. In the maturing process of Pedah-Siam, a strain of non-spore forming bacteria seemed to induce the characteristic Pedah flavour. This strain was highly resistant to salt and was able to grow under both aerobic and anaerobic conditions.

(iv) **Physical properties.** Inuzuka (13) examined physical properties of the pickle withdrawn from an experimental preparation of "Ika-shiokara" containing 20 per cent NaCl. According to his results of measurement on density, viscosity, surface tension and optical rotation of the pickle, optical rotation and density seemed to indicate the increase of their values parallel to the "ripening" of the product. In these physical characteristics of the pickle, optical rotation should be affected by the liberation of optically active amino acids, and was presumed to be useful for estimating the progress of fermentation. Viscosity of the pickle also varied with storage time, whereas surface tension showed practically no change (Table IX).

TABLE IX

Changes in the values of density, viscosity, surface tension and optical rotatory power of the pickle obtained from "Ika-Shiokara" (fermented squid)

(Inuzuka, 1933)

Time of storage at 25°C in days	*Density*	*Viscosity*	*Surface tension*	*Rotation*	*NaCl %*
2	—	—	51·70	0·47	16·43
4	1·201	2·896	51·68	0·60	16·45
6	1·205	2·916	51·70	0·58	16·87
9	1·206	2·950	51·65	0·50	16·45
11	1·208	3·123	51·68	0·45	16·73
13	1·213	3·469	51·72	0·95	16·24
16	1·211	3·431	51·70	0·65	17·43
19	1·212	3·424	51·70	1·02	15·75
22	1·214	3·546	51·72	1·52	16·38
25	1·215	3·608	51·70	1·62	16·48
28	1·216	3·670	51·72	1·81	16·53

4. Chemical composition of the commercial products of Group (I)

(i) **Nitrogenous compounds.** The fermented fish, fish paste, and particularly fish sauce are definitely foodstuffs of nitrogen source. As indicated in Table X, the protein content of fermented fish and fish paste ranges from 50 to 80 per cent (moisture- and salt-free basis).

It is difficult to observe the extent of nitrogen loss before and after fermentation, since no information following the change from raw fish to finished product is available. Table X shows that the average content of protein in raw fish, such as anchovy or rastrelliger, is about 80 per cent (moisture-free basis). The loss in nitrogen compound taking place during fermentation will be 30–35 per cent of total nitrogen originally contained, for the products of Makassar fish, Ngapi, and Pedah-Siam. The relatively little loss counted for Shiokara may be due to lack of drainage during processing.

In fish sauce fermentation, a comparatively good yield of nitrogen may be assured for the superior quality product. If there were no addition or no evaporation of water, the concentration of total nitrogen in the pickle would be 2·5 per cent for fish like anchovy.

TABLE XI

Chemical composition of fermented fish sauce simply mixed with salt

(*Fisheries Products Manual*, 1961)

	Nuoc-mam first quality	*Nuoc-mam ordinary quality*	*Patis extra*	*Nam-pla high grade*	*Nam-pla low grade*	*Fish sauce from sardine*
NaCl	27·5	28·0	28·21	28·15	28·90	20·0
Total-N	2·2	1·1	2·20	1·92	0·92	2·64
Organic-N	1·5	0·75	2·02	1·64	0·62	—
Formol-N	1·6	0·8	1·18	1·13	0·83	1·44
Ammonia-N	0·7	0·35	0·18	0·28	0·28	0·13

In Table XI, total nitrogen values of varieties of fish sauce are shown ranging from 0·92 to 2·64 per cent. Such a big difference in the nitrogen content of fish sauce is simply due to dilution of the residue of the fermented fish from which the first pickle has been removed.

Table XII′ gives a typical change in the chemical composition of commercially produced Nuoc-mam at various stages of fermentation. In these figures, one can see that 2·5 per cent of total nitrogen is obtainable during fermentation. In fact, the nitrogen of raw fish can

TABLE X

Chemical composition of fermented fish and fermented fish pastes

		Makassar fish from anchovy	*Ngapi from shrimp*	*Pedah-Siam from rastrelliger lean fish*		*Trassi*	*Trassi udang*	*Trassi ikan*	*Belachan*	*Kapi*	*Shiokara from squid*	*Shiokara from skipjack entrails*
Moisture . .	%	65·8	43	44–47	44–47	38·2	55–57	25–50	27–40	38·95–45·33	74·20	64·42
NaCl . .	%		22	15–17	12–18		15–20		13–18	18·81–23·93	7·82	23·93
Protein . .	%	15·0	20	21–22	26–37	38·7		20–45	30–40	15·93–24·87	11·60	8·24
Fat . .	%	0·4	2	7–15	1·5– 7	3·4			1·4–2·6		2·83	1·07
Ash . .	%	16·9	27			12·4			20–24	23·51–29·70	8·68	26·32
Ammonia .	%		0·6									
Raw Fish:												
Protein (moisture- and salt-free basis)	%	55	57	52–47	59–?	78		—	50–95	36–80	68	69
Protein (moisture-free basis)	%	80[1]	83[2]	80[1]							85[2]	71[3]
Loss in protein before and after fermentation. . . .	%	31	31	35							20	3

Analytical figures are extracted from the *Fisheries Products Manual*, edited by Subba Rao, 1961.

[1] The figures are taken from "Proximate chemical composition of various species of Philippine market fish", *Philippine Journal of Fisheries*, 2, 109–122, 1953.

[2] From *Standard Tables of Food Composition in Japan*, 94, 1953.

[3] From "Studies on the enzymes of skipjack entrails", *Bull. Jap. Soc. Sci. Fish.*, 18, 151–154, 1952.

TABLE XII

Chemical composition of Nuoc-mam at various stages of fermentation

(Uyenco *et al.*, 1952)

Liquid samples drawn from mixture of fish and salt in vats	*Nitrogen in grams per litre*				
	Total-N	*Organic-N*	*Formol-N*	*NH_3-N*	*Amino acid-N*
Liquid recovered after 3 days	7·7	6·5	—	1·2	—
Liquid recovered after 1 month	17·1	14·5	7·9	2·6	5·3
Liquid recovered after 2 months	19·0	16·2	12·1	2·8	9·3
Liquid recovered after 5 months	25·5	22·8	15·7	2·7	13·0
Non Nuoc-mam (leachings)	8·4	4·3	6·6	4·1	2·5
First leaching	5·0	0·9	4·5	4·1	0·4
Second leaching	4·5	1·0	3·7	3·5	0·2

be made better available by making fish sauce than by other types of fermentation, provided there is no loss in nitrogen caused by bacterial breakdown.

(ii) **Amino acid composition.** Nagasaki and Yamamoto (26) made quantitative determination of amino acids in fermented squid. They noticed the monoamino acid fraction was always higher than diamino acid fraction throughout the course of ripening. The ratio of monoamino acid to diamino acid after 31 days of storage was 4·8 : 1·0. Shimidu (34) mentioned in his work on the fermented skipjack entrails that, of hot water soluble nitrogen, one third was monoamino acid fraction at the start of fermentation, and this increased to nearly two thirds after a month's standing.

These findings may suggest that the product flavour is largely influenced by monoamino acid fraction. Nagasaki and Yamamoto identified 15 varieties of amino acids in "Ika-shiokara" by paper chromatography. These amino acids were: aspartic acid, glutamic acid, glycine, alanine, leucine, proline, valine, histidine, β-alanine, tyrosine, arginine, serine, cystine, ornithine, and taurine.

Information is scarce concerning quantitative distribution of amino acids in fermented fish. In Table XIII, the results of determination of different amino acids in both Ngapi and Nuoc-mam are shown, with reference to the data for sardine flesh. Unfortunately, no description of quantitative change of individual amino acids during the fermentation process was available, but the essential amino acids were found in fairly good retention in both Nuoc-mam and Ngapi.

Tryptophan was reported not present in Ngapi; but in Nuoc-mam, a potency from 0·17 to 0·86 g. per liter was described by Autret and Bouvier (2).

Tyrosine content, as reported by Vialard-Goudou (45), lies between 1·21 and 2·40 g. per liter of Nuoc-mam. It is larger in superior quality products.

TABLE XIII

Amino acid content of fish paste and fish sauce (Ngapi and Nuoc-mam) with reference to sardine flesh

(*Fisheries Products Manual*, 1961)

	Ngapi[1]	*Nuoc-mam*[2] *(ordinary quality)*	*Sardine*[3]
Alanine	9·3	4·2	7·3
Arginine	5·8	2·0	6·9
Aspartic acid	5·6	2·4	11·2
Cystine	—	0·25	—
Glutamic acid	8·8	4·0	14·7
Glycine	8·5	2·4	5·6
Histidine	2·1	0·3	2·5
Isoleucine	3·8	4·0	6·0
Leucine	5·9	4·0	9·3
Lysine	8·4	4·0	11·0
Methionine	1·3	0·8	3·6
Phenylalanine	2·3	1·5	4·7
Proline	3·0	0·5	4·0
Serine	—	0·8	5·1
Threonine	2·7	2·0	5·6
Tyrosine	1·4	0·8	4·4
Tryptophan	—	0·5	1·3
Valine	4·3	3·0	7·4

[1] As grams of amino acid N per 100 grams of dialysable N.

[2] As grams per liter, for superior quality sauce, the above figures should be multiplied by 1·6–2·0.

[3] As percentage in moisture- and ash-free protein. Taken from Konosu *et al.*, "Amino acid composition of fish muscle protein", *Bull. Jap. Soc. Sci. Fish.*, 21, 1163–1166, 1956.

(iii) **Oil.** The amount of oil differs with the individual product, as seen in Table X. No doubt it depends upon the oil content of the raw material. But the oil in the fermented fish may have little importance from a nutritional viewpoint. The presence of salt will accelerate the oxidation of oil, and possibly the impurities of salt may play a greater part in oxidation and rancidity. These deterioration products of fish oil may adversely affect human nutrition. But sometimes, fermented fish is prized because of the oxidation of oil: for example in Pedah-Siam, prepared from mackerel (*Rastrelliger* sp.) in Thailand and exported to Indonesia and Malaya. The brown colour of the best qualities is due to oxidation of body oil.

In a particular operation in the manufacture of Nuoc-mam prepared from Ca-moi (*Dorosoma nasus*), lots of oil drifts on the product during maceration. Chemical properties of this oil were 2·50–20·05 of acid value; 131–161 of iodine value; 188–191 of saponification value; and 2·20–2·93 per cent of unsaponifiable matter.

Using a storage test of fermented yellowtail entrails, Fukuda (9) found acid value of oil extracted from the product increased to 20–30 after a lag period of 10 days, whereas peroxide value of the oil indicated a peak at the end of a week of steady increase. It then went down. The amount of oxidized acid in the oil also rose with storage time, and showed a value of 15 per cent in the oil after a month's storage.

Fukuda suggested formation of oxidized acid could be suppressed by addition of an antioxidant such as BHA (Butyl hydroxy anisole). Addition of 0·01 per cent of BHA to the product enabled it to be kept in good condition more than 2 months.

There remains the possibility of forming fatty acids by fish muscle's own lipase. Wood (49) tested the lipolytic activity of enzyme preparation from ling cod muscle. He found both monoglycerides and triglycerides were hydrolysed readily; but the triglycerides containing long-chain fatty acids such as trioctanoin were not attacked.

(iv) **Salt.** Salt content is usually high in the fermented fish pastes and fish sauce. It amounts to about 20 per cent in the average product. The salt problem may result in two effects: direct and indirect. The first factor is an overdose through the heavily salted fermented fish, which adversely affects the human system. But, even in Vietnam, where a 40 g. daily intake of Nuoc-mam per person is reported as normal, it corresponds to 11 g. of salt, which is hardly recognized as an overdose. In addition, salt can be lost through perspiration in tropical climates, and people in the region may tolerate a rather high salt intake.

The second factor may be that a high salt content inevitably prohibits a large intake of these products of animal protein source; so possibly it may cause a part of protein deficiency, which might be avoided if lightly-salted fish could be used.

GROUP II: TRADITIONAL PRODUCTS, FERMENTED BY COMBINED EFFECTS OF FISH ENZYMES AND MICROBIAL ENZYME, MICROBIAL ENZYME PREPARED AND ADDED AS A STARTER IN ADDITION TO SALT

Nearly 20 varieties of fermented fish are in this group. The group includes pickled fish (Burma), Mam-chao (Cambodia), Makassar fish (Indonesia), Funasushi (Japan), Buro (Philippines), and Pla-ra (Thailand). These products are shown in Appendix II.

The preparation process is characterized by the use of starters. These may be simply cooked rice, roasted rice, Koji (cooked rice on which *Aspergillus oryzae* is planted), Angkak (rice fermented by a red yeast-like organism "*Monascus purpureus*"), Ragi (a Javanese preparation made from yeast and rice), maize, rice bran, sugar, honey, pineapple, and spices, etc.

Fermentation of this type is in two steps. The first is salting fish after beheading and evisceration, and sometimes removing bones and tail. The second is mixing the starters. The variety of starters differs with production locale.

By evisceration, the possibility of maceration by proteolytic fish enzyme may be reduced to some degree. However, the addition of mould preparations or carbohydrate sources may offer another type of fermentation, which is hardly seen in group (I) products.

In countries like India, East Pakistan or Ceylon, tamarind (*Garcinia camboges*), an acidic legume, is commonly mixed into fermented fish products.

1. Chemical changes during the "ripening" of Funasushi.

Matsushita (20) made biochemical studies on the Japanese "Funasushi", a fermented fresh-water fish with cooked rice as a starter, which may be related to Cambodian "Mam-chao". The raw material of "Funasushi" is Crucian carp of about 400 g., caught in May just before spawning.

After scaling and evisceration, retaining the roe, one part of the fish is placed in a barrel with one part of salt and kept for 2 months under pressure of stone. Then the heavily salted and flattened fish are taken out and soaked in water to remove salt. The salt is almost completely removed, the fish is drained, then packed in a barrel with an equal amount of cooked rice, to which Koji has been mixed. The mixture is pressed again with stone. It starts gas formation the next day and begins about 10 days of active fermentation. The product may be ready to use after 2 months' storage. The product has a penetrating odour.

Chemical changes during this process will be seen in Table XIV.

TABLE XIV

Changes in the chemical composition during preparation of Funasushi (per cent in dry matter)

(Matsushita, 1937)

	Raw fish		*Salted fish (after salting a month)*		*Funasushi (finished product)*	
Moisture . .	73·23		79·02		72·52	
Dry matter .	26·77	100·00	20·98	100·00	27·48	100·00
Protein . .	—	48·46	—	34·36	—	38·69
Gelatin-forming protein. .	—	27·35	—	19·69	—	25·18
Soluble matter .	—	14·90	—	26·73	—	22·22
Soluble protein.	—	2·75	—	1·74	—	2·22
Carbohydrate .	—	—	—	—	—	3·48
Ether extractives	—	16·96	—	12·03	—	21·74
Ash . .	—	6·53	—	10·01	—	7·62
Total acid (as lactic) .	—	—	—	—	—	7·33

Up to 20 per cent protein has been lost in salting, but 5 per cent is regained, perhaps from the cooked rice. Loss of water soluble matter in the finished product is due to removal of salt by soaking salted fish. Reduction of ether extractives in salted fish is supported by partial removal of fat. The increase in that of finished "Funasushi" may be attributable to lactic acid production.

TABLE XV

Chemical composition of the fermented cooked rice removed from Funasushi after 80 days' fermentation (per cent)

(Matsushita, 1937)

Moisture	67·31
Total solid	33·69
Soluble solid	13·38
Ash	4·02
Volatile acids	0·18
Non-volatile acids	1·68
Alcohol	3·80
Sugar	2·46
Dextrin	3·77
Starch	7·95
Total nitrogen	1·82

Major parts of non-volatile acids confirmed was lactic acid.

Analytical data of the fermented rice removed from "Funasushi" after storage of 80 days are shown in Table XV.

The flavour and odour specific to the product could be derived from these decomposition products.

2. Major microorganisms concerned with fermentation of "Funasushi"

Bacteriological examination of "Funasushi" indicated that the predominant species carrying out fermentation was *Lactobacillus plantarum*, an active former of lactic acid. There were also isolated *Lactobacillus pentoaceticus*, *Streptococcus faecium* and three kinds of yeast.

These lactic acid bacteria were found able to stand pH value as low as 2·8, but salt not more than 4·8 per cent. Matsushita assumed that the amount of 2 per cent lactic acid in "Funasushi" caused softening of the fish bones and should make the product more palatable.

No scientific work is available on the medicinal effect of "Funasushi". However, people accustomed to eating this peculiar food believe it is a good remedy for gastro-intestinal upset. Whether this is due to the metabolic products of the lactic acid bacteria, may be worthwhile investigating.

3. Chemical composition of some Vietnamese fermented fish in Group (II)

From Table XVI it is seen that Vietnamese fish pastes contain less moisture and protein than "Funasushi". Protein content on a moisture- and salt-free basis varies from 47 per cent to 61 per cent—almost the same as for fermented fish of group (I). Rough estimation of loss in protein are 28 per cent for *Clarias* and 49 per cent for *Ophicephalus*.

TABLE XVI

Chemical composition of fermented fish paste added roasted rice with salt of Vietnam

(Nguyen-Thi-Lau and C. Richard, 1959). From *Fisheries Products Manual*, 1961.

		Mam Ca-loc	*Mam Ca-sat*	*Mam Ca-tre*	*Mam Ca-ro*	*Mam Ca-linh*
Moisture	%	45·55	52·60	50·35	51·27	58·22
NaCl	%	5·82	6·15	6·03	6·07	6·50
Protein	%	22·57	20·10	26·25	21·87	21·87
Carbohydrate	%	20·31	14·87	7·14	15·61	1·30
Fat	%	1·08	0·93	0·69	2·02	4·00
Ash	%	10·75	11·50	15·57	9·43	14·61
Protein (moisture- and salt-free basis)		47	49	60	51	61
Protein (moisture-free basis)		93[1]	—	83[1]	—	—
Loss in protein before and after fermentation		49	—	28	—	—
Raw material		*Ophicephalus striatus*	*Trichogaster trichopterus*	*Clarias fuscus*	*Anabas testudineus*	*Dangila* sp.

[1] Figures are taken from "Proximate chemical composition of various species of Philippine market fish", *Philippine Journal of Fisheries*, 2, 109–122, 1953.

4. Use of mould preparation in the processing of fish paste

Since the preparation of *Aspergillus oryzae* has been so extensively utilized, particularly in the industry of "Miso" (soybean paste) and "Syoyu" (soy sauce) manufacture in Japan, Tanikawa *et al.* (42) applied a proteolytic strain of *Aspergillus oryzae* to hasten the ripening of fish paste. They prepared an experimental pack, consisting of 75 parts of chopped raw flesh of atka mackerel, 15 parts of salt and 10 parts of starter (a wheat bran inoculated with proteolytic *Aspergillus oryzae*), and kept the whole mixture for 45 days at 30–35°C.

Experimental results showed water content increased to 73·0 per cent at the end of fermentation from an initial level of 61·8 per cent. pH value reached 4·6 after 17 days from the initial value of 5·8 and increased again to 5·8 at the end. The percentage content of non-protein nitrogen to total nitrogen was 69 per cent at the start of inoculation and 92·5 per cent at the end, while the proportion of amino acid content to non-protein nitrogen was 13·5 per cent at the beginning, increasing to 60·0 per cent at process termination.

In the latter part of the fermentation, ammonia development was so remarkable that flavour was almost intolerable. The recommendation of the workers was heat processing at the middle of fermentation to control undesirable change. They chose the time when pH value of the mixture had reached as low as 4·6.

On the other hand, acid value of the oil in the product rose from 16·5 to 22·4 after 40 days, whereas iodine value showed a decrease from 142 to 130 in the same storage period.

When the proportion of starter to fish flesh was increased to 20 per cent, salt concentration required to minimize ammonia formation was found to be 15–18 per cent, though it retarded the rate of amino acid production.

Takei *et al.* (41) tried a similar run of experiments, fermenting squid flesh by adding "Koji" (*Aspergillus* preparation of wheat bran and potato). He reported a mixture of "Koji" and meat in a ratio of 1 : 1 invariably gave the best paste. When the ratio was 1 : 2, fermenta-

TABLE XVII

Changes in the chemical composition of the mixture of plaice meal and the preparation of *Aspergillus oryzae* during storage at 30°–40°C

(Higashi *et al.*, 1951)

Time of mould growth in days		0	2	5	8
Total weight of the mixture	g.	100	83·0	71·7	66·2
Moisture	g.	35·2	29·3	21·4	19·9
Total nitrogen	g.	4·31	4·32	4·29	4·05
Starch	g.	21·6	8·8	8·3	6·3
Crude fat	g.	4·82	2·40	1·02	1·01
Unsaponifiable matter	g.	0·197	0·175	—	0·200
Unsaponifiable matter in crude fat	%	4·1	7·3	—	19·8

Each figure is expressed in terms of 100 g. of the starting material.

tion was retarded. With a 1 : 3 ratio no paste was obtained.

Higashi *et al.* (12) examined chemical changes which took place in fermented paste prepared from fish meal with the aid of fungus preparation (*Aspergillus oryzae*). They found a remarkable decrease in oil, but no decrease was noticed in nitrogen. By a spectrophotometric technique, they observed a possible formation of ergosterol in the unsaponifiable fraction of oil which showed a marked increase by the fungal growth (Table XVII).

They prepared the fish paste by the fungal action on fish meal, after boiling the fish meal with 1 per cent NH_4OH and making it swollen, then adding a cooked mixture of rice, barley, and potato starch. They next planted the culture of *Aspergillus oryzae* and incubated the whole mixture for 3 to 5 days at 30–40°C. The finished product gave a smooth consistency, which was hard to obtain if it was not processed with hot ammonia solution.

There are some other uses of mould preparations in commercially produced fermented fish. "Koji", a preparation of *Aspergillus oryzae*, is often incorporated in the middle of fermentation of "Ika-shiokara". The purpose of mixing "Koji" is to neutralize the salty taste of the product by dextrose which generates from "Koji" by amylolytic activity of *Aspergillus oryzae*, and not further microbial development which may impart souring or other types of flavouring in "Ika-shiokara".

Addition of Angkak to certain kinds of fermented fish may be interpreted as a simple food colouring. It is used for products such as Bagoong Alamang in the Philippines. Dried Angkak is added after pulverizing to give an even colour.

5. Use of natural mould growth on "Katsuobushi", a smoke-dried skipjack

"Katsuobushi", a traditional processed fish in Japan, may be roughly grouped into smoked and dried products depending on the way of manufacturing. In the latter part of processing, fermentation by mould plays an important rôle. Skipjack is usually subjected to a month-long process of fungal growth after boiling, cleaning and repeated smoke-drying.

There has been no decisive view on the significance of moulding in the process of making "Katsuobushi", though the industry has been working many years on this particular process, believing the process is compulsory to obtain good flavour. Some Japanese biochemists recently reported the changes in nitrogenous compounds, oil and moisture during the process of repeated mould growth.

Many varieties of mould, including *Torula*, *Penicillium*, *Cladosporium* and *Aspergillus* may grow on the half-dried, boiled fish in mixed culture. Fungal growth normally takes place when the fish is stored in air-tight wooden cases.

After a week's storage in the case, the fish is taken out, placed in the sun to dry, then put back into the case after brushing off surface moulds. This process will be repeated 5–10 times before "Katsuobushi" is sold. Consequently, the variety of microflora will change from moisture-loving *Penicillium* or *Torula* to a certain kind of *Aspergillus* highly resistant to desiccation, according to gradual decrease in water content of the product.

(i) **Effect of mould on the nitrogenous compounds.** Probably the only significant loss in nitrogenous extractives should occur when the fillet of raw fish is subjected to boiling for about an hour. It amounts to some 17 per cent.

Konosu and Hashimoto (18) examined the changes in free amino acid before and after mould growth on "Katsuobushi" and observed that most of the free amino acids decreased in amount. However, some amino acids such as threonine and serine retained the original level possessed in fish flesh.

Aspartic acid was the only one which newly appeared after the moulding process. The amount was quite small.

Kanazawa and Kakimoto (14) noticed an appreciable increase in both glycine and glutamic acid when they inoculated and sterilized fish with *Aspergillus ruber* and *Aspergillus repens*, and assayed after 40 days' culture at 30°C. Their findings differed from those presented by Konosu and Hashimoto. The difference was perhaps due to comminution of the fish flesh prior to inoculation, which probably permitted a large surface of flesh to be attacked by the moulds.

Konosu and Hashimoto noticed an interesting fact: decrease in trimethylamine and trimethylamine oxide (TMAO), by moulding. TMAO particularly was completely lost by the process.

(ii) **Effect of mould on oil and moisture.** Fungal growth causes characteristic changes in the oil of "Katsuobushi",

TABLE XVIII

Changes in chemical characteristics of oil of "Katsuobushi" during processing, particularly by moulding process

(Suyama, 1949)

Oil from	*Time elapsed*	*Color of oil*	*Refractive index·d^{20}*	*Acid value*	*Iodine value*	*Saponification value*	*Ester value*
Fresh meat	0 day	Light yellow	1·4842	4·67	194·5	199·7	195·0
Boiled meat	0	Yellow	1·4842	6·05	190·7	197·4	191·3
The meat after first smoking . .	1	Yellow	1·4852	8·20	185·1	204·4	196·2
The meat after eighth smoking . .	8	Reddish brown	1·4856	9·51	164·4	205·8	196·3
The meat after moulding for 6 months	(6 months)	Reddish brown	1·4820	124·7	182·7	185·1	60·4

TABLE XIX

Changes in the distribution of moisture at the different depth of "Katsuobushi" during moulding process (per cent)

(Suyama, 1950)

	Fish after 8th smoking before moulding	*After 1st moulding*	*After 2nd moulding*	*After 3rd moulding*	*After 4th moulding*	*After 5th moulding*
1st layer (0–1·5 mm.) .	12·34	12·44	14·04	14·04	15·25	15·05
2nd layer (1·5–3·0 mm.) .	15·83	16·09	17·54	17·06	17·37	16·53
3rd layer (3·0–4·5 mm.) .	19·08	18·79	19·23	18·69	19·13	18·24
4th layer (4·5–6·0 mm.) .	21·50	21·08	20·80	20·02	20·57	19·65
Lapse of time in days .	0[1]	12	28	42	57	75

[1] A month has passed after boiling and smoking started.

since oil normally locates right beneath the skin and can be ready for biochemical action of the moulds.

Suyama (38) tested chemical changes in oil of "Katsuobushi" prepared from the belly side of the fish during the course of boiling, smoking and moulding. From Table XVIII, it is obvious that the smoking process prevents the boiled skipjack from oxidation of oil, as indicated by decrease in iodine value from the fish immediately after boiling, compared to that smoked 8 times repeatedly.

A tremendous increase in acid value from 9·5 to 125 after the moulding process is indicative that lipolytic reaction takes place by lipase from the mould. This could be supported by the increase in iodine value. Decrease in both saponification value and ester value also suggests the lipolytic breakdown of fish oil during fungal growth.

It is noteworthy that the oil extracted from the moulded fish can always be free from fishy odour. This may be the reason why "Katsuobushi" is used as a soup base without objection.

Suyama (39) conducted a more detailed examination into how deep the mould can affect chemical changes from the surface of the strip of fish. And he found that the increase in acid value of oil was observed even at a depth of 4·5–6·0 mm. from the surface of the product, and concluded the lipolytic activity of the mould was able to penetrate to this depth. Suyama also pointed out a possibility for the migration of moisture from inside to outer surface of the product by the aid of fungal growth (Table XIX).

His belief came from a control test of drying skipjack in a desiccator without inoculating mould. He found many cracks occurred on the control fish subjected to artificial drying, while no such damage was observed in the inoculated sample even when the moisture content was the same as in the control.

GROUP III: NON-TRADITIONAL PRODUCTS MANUFACTURED BY ACCELERATION OF FERMENTATION, ACID ENSILAGE AND CHEMICAL HYDROLYSIS

A. Acceleration of Fermentation

The industry feels the need to expedite fermentation of such products as fish paste and fish sauce. Generally they require 6 months to a year of maceration or hydrolysation. If possible, the storage period of 6 months for Bagoong, for example, should be shortened to a month.

1. Effect of temperature raise

The idea of raising the conserving temperature of fermented fish may be feasible. The practice of placing the container with the product directly in the sun, partly adopted by the South-east Asian industry, may be based on experience of rather quick maceration in a naturally heated container.

Shimidu and Utida (36) tested the effect of various temperatures on the formation of amino acids by autodigestion of pyloric caeca of skipjack within a pH range of 5·00 and 7·00, with half salt-saturation. After a week of storage, a maximum yield of amino acid was obtained at 55°C, regardless of pH conditions given in the experiment. However, after 3 weeks' storage, the yield was always higher in a batch kept at 37°C, at any pH value provided. Freeman and Hoogland (6) reported that autolysis of viscera from cod and haddock progressed rapidly at 37°C as well. Hamm and Clague (11) suggested temperatures of 45°C for periods of 1–2 weeks as a practical means of speeding up Bagoong (fish paste) manufacture. But exposure to temperature higher than 45°C was not recommended (Table XX).

TABLE XX

Protein content of liquid portion of slipmouth Bagoong, stored in hermetically sealed containers

(Hamm and Clague, 1950)

Storage temperature	*Protein content after storage period of* *7 days* %	 *14 days* %	 *28 days* %
Room temperature .	4·13	5·24	6·40
37°C. . . .	5·11	6·36	7·72
45°C. . . .	6·97	8·01	8·93

Retardation in autolytic process can be caused by increase of added salt, but certain concentrations of salt may provide a protective effect against heat inactivation of enzyme. For example, ptyalin could be more heat resistant at a NaCl concentration from 0·5 to 0·7 per cent.

Takahashi (40) proved the protective effect of salt on the heat inactivation of enzyme prepared from pyloric caeca of yellowtail. He found that the enzyme was inactivated at a NaCl concentration lower than 1 per cent kept at 50°C. With increase of salt concentration, enzymatic activity appeared to increase to a maximum at 2 per cent and kept a similar activity up to 15 per cent; then decreased when salt amount became higher than 15 per cent.

From these findings, methods of raising temperature for accelerating fermentation in traditional products of group (I) will be restricted to a temperature range of 37°–45°C. A quick digestion method without salt was proposed to prepare a fish autolysate under sterile conditions by adding 2–3 per cent nitrochloroform. The auto-digestion was over within a few days, and the autolysate contained 1·5 times as much autolysed product as conventional Nuoc-mam. This product, however, has not been well received by the people. They preferred the penetrating specific odour of conventional Nuoc-mam.

Shimidu and Utida also examined the effect of pH on amino acid formation by pyloric caeca, stomach and liver of skipjack. A pH range from 3·02 to 8·00 was tested. They found amino acid was abundantly formed near a pH value of 7·00 by these three enzyme sources. Pyloric caeca showed wider optimum pH range than the others.

2. Use of enzyme preparation

There have been suggestions for use of papaya or pineapple juice as possible hastening agents in tropical countries. They have not been taken up by the industry yet. However, Ngo-Ba-Thanh (28) mentioned good results, particularly when pineapple was used as proteolytic enzyme. It may be due to the fact that enzyme potency of these fruits is not reliable, but varies with their maturity to a great extent. In addition, it may become a problem of economics if the enzyme should be refined into concentrated form to enrich potency. Now, new enzyme preparations are becoming commercially available, and some of these are being applied to the fish soluble industry in Japan. These preparations are chiefly made from proteolytic strains of *Bacillus subtilis*, and about 0·4 per cent of the powdered enzyme preparation to the amount of fish may be required to complete liquefaction of fish in 3–5 hours at 50°C.

Meinke (21) suggested the use of enzyme preparation for visceration and scaling of trash fish caught while shrimp fishing along the Texas Gulf Coast. He noted that proteolytic enzymes of bacterial origin with a high temperature optimum are most desirable.

One of the enzyme preparations now being manufactured in Japan possesses optimum temperature in a range of 45°–50°C and has two different optimum pH values. The first is 7·0 and the second is 10·5, when casein is used as a substrate.

But Freeman and Hoogland (7) noticed that the addition of enzyme preparation to viscera offered no advantages, since natural enzymes in the haddock and cod viscera which they used contained enough potency to digest their own tissues.

Unfortunately, no information has been available concerning application of enzyme preparations for fermented fish products in human use, leaving the possibility for future investigation. The main problem to be taken into consideration may be the sort of bitter taste perceived in autolysate of fish treated by this means. Certain deterioration products from fish protein might be causing the unpleasant flavour.

B. Acid Ensilage and Chemical Hydrolysis

1. Acid ensilage

For the purpose of animal feeding, trials were made in Denmark. Olesson and Olofsson (30) obtained fish ensilage with good keeping quality by the use of 1·5 liters of formic acid, or by the use of 20 kg. of molasses per 100 kg. of finished ensilage. However, a chick feeding test gave slightly better growth when chicks were fed with fish meal than was obtained with fish ensilage.

Freeman and Hoogland (6) described a formula to prepare acid ensilage from cod and haddock offal. A 5-lb. portion of concentrated sulfuric acid is required to treat 100 pounds of offal to which 4–5 gallons of water were added.

Complete digestion requires 2–3 weeks for the mixture at room temperature. Composition of finished product may contain 24·4 per cent dry matter and 14·5 per cent protein with an average pH value of 2·05. And 2·5 lb. of powdered lime stone or chalk is required to neutralize 100 lb. of the ensilage. Retention of B vitamins in the ensilage reported were: 4 ppm. thiamine, 1 ppm. riboflavin, 20 ppm. niacin, 2 ppm. pantothenate and 0·015 ppm. B_{12}.

2. Acid hydrolysis

Chemical hydrolysis of fish by means of strong acids or alkalis may not be in the realm of this article. However, it might be adopted, if the hydrolysis could be properly combined with the natural fermentation process as is presently being done in the soy sauce industry. The unavoidable problem in hydrolysis of fish is the repulsive odour specific to the hydrolysate. The soy sauce industry is now mixing with the autolysate naturally processed "Koji" (*Aspergillus* preparation), since it ensures masking of disagreeable odour.

When HCl is used for hydrolysis, 15–20 per cent may be recommended as a final concentration. More than 20 per cent HCl will be useless because this level is a maximum concentration when heat processing is conducted and excess HCl will be lost by evaporation. According to Kaneda and Saito (15), about 4 hours of digestion will be enough and maximum proportion of amino acid nitrogen to total nitrogen will be in a range of 60–65 per cent in the hydrolysate.

3. Alkali hydrolysis

Because acid hydrolysis might destroy some of the amino acid, Mohanty and Roy (22) tried to hydrolyse fat-free protein prepared from shark and ray flesh, with 10–12 per cent NaOH at 80°C. This hydrolysate was neutralized with 85 per cent acetic acid and was then spray-dried. Thus, a 10 per cent yield of a cream-coloured powder containing 85 per cent protein was obtained.

Approximate percentage composition of amino acids in the new product is indicated in Table XXI.

TABLE XXI

Approximate percentage composition of amino acids of the protein from waste fish

(Mohanty and Roy, 1955)

	Egg albumin	*Protein from waste fish flesh*
Cystine	1·9	0·49
Lysine	5·0	1
Histidine	1·7	2·5
Arginine	5·9	2·5
Serine, glycine, aspartic acid	18·7	7·3
Threonine, glutamic acid	21·5	12·9
Alanine	7·2	1·5
Tyrosine	11·9	8·0
Leucine, isoleucine	17·1	5·3

4. Condensation of fish sauce

Attempts have been made to evaporate Nuoc-mam in *vacuo* at 50°C. The product is reduced to a fifth of its original volume. By mechanical condensation, there is slight loss of amino nitrogen, and a decrease in NH_3 nitrogen. Table XXII indicates the changes in the composition of vacuum-dried Nuoc-mam.

TABLE XXII

Chemical composition of powdered Nuoc-mam with reference to liquid Nuoc-mam

(Ngo-Ba-Thanh, 1953)

	Liquid Nuoc-mam %	*Powdered Nuoc-mam* %
Water	64·46	3·79
Ash (excludes NaCl)	0·25	0·43
NaCl	22·75	43·25
Organic matter	12·54	52·53
Total nitrogen	1·61	4·36
Non-protein-N	1·55	4·24
Amino-N	1·03	2·50
Volatile base-N	0·249	0·266
Ammonia-N	0·241	0·249
Volatile amine-N	0·008	0·017
Acid (as acetic)	0·058	0·235
pH	5·65	5

MINOR COMPONENTS OF NUTRITIONAL IMPORTANCE

1. Vitamins

Salting and fermenting are inevitably accompanied by oxidation, and vitamin A is quite apt to decay. Pyloric caeca or kidney of pelagic fish normally contains about 10,000 I.U./100 g. of vitamin A, but the content of this vitamin in the fermented paste of skipjack entrails was only 130–650 I.U./100 g. The fresh pyloric caeca of skipjack should have 30,000 I.U./100 g. of vitamin A.

As to the carotin content, fermented entrails of abalone showed 1,800 μg./100 g.; fermented sea urchin contained 2,500 μg./100 g., and crab roe 1,400 μg./100 g.

The vitamins of the B group are, in general, easier to conserve than those of the A group. In the varieties of fermented products prepared from entrails, B vitamins can maintain their original potency after a certain period of fermentation. Normal potency of B_2 in the flesh portion of fish varies from 0·5 to 2·0 μg./g., and these values can be almost perfectly restored during the process.

Pantothenic acid can also retain its potency in the fermentation process. The amount of 39·4 μg./g. of pantothenic acid was reported in fermented crab roe.

Vitamin B_{12} is fairly resistant against loss due to fermentation. Between 2·5–20 μg./100 ml. of B_{12} in Nuoc-mam has been reported. In addition, vitamin B_{12} seems to increase in fish by bacterial decomposition. Mori *et al.* (23) stored samples of fresh carp, eel, goby, mackerel, horse mackerel, trout, clams and crab, and noticed the interesting fact that B_{12} apparently increased during spoilage in fish stored in minced form at 32°C. A decrease of B_{12} was observed in the same species when these were kept in the round (Table XXIII).

TABLE XXIII

Changes in the vitamin B_{12} content of marine animals during spoilage at room temperature (μg./100 g. (wet basis))

(Mori *et al.*, 1954)

		Storage in days					
Species	*Treatment*	*0*	*1*	*2*	*3*	*4*	*5*
Mackerel flesh	round	1·9	1·0	—	0·8	—	0·8
	minced		1·8	—	0·8	—	1·0
Mackerel liver	round	40·0	34·0	—	+	—	—
	minced		40·0	—	36·0	—	36·0
Baby clam	minced	1·5	1·8	3·5	—	5·5	—
Swimming crab meat	minced	1·8	1·8	1·5	1·5	—	1·6
Swimming crab liver	minced	3·0	2·8	2·8	2·8	—	2·8

These findings may suggest a possibility of good retention of B_{12} in the fermentation where bacterial growth might take place to some degree.

Vitamin B_1 content in Ngapi ranges from 110 to 137 μg./100 g., but there is almost none in Nuoc-mam. Since Nuoc-mam has to be exposed to the sun for 3–10 months, destruction of B_1 or B_2 may occur, particularly in fish placed on top of stock, according to the report of Ngo-Ba-Thanh (28). The possibility of destruction of B_1 vitamin by thiaminase in the fish entrails has not been confirmed.

2. Minerals

Certain crustacean products, such as fermented crab or shrimp, and products from abalone and skipjack entrails, may be accepted as a source of calcium. Calcium content of fermented plankton shrimp is 512 mg. per cent; 190 mg. per cent for fermented skipjack entrails. Bagoong Alamang, Kapi, and Ngapi, all prepared from small shrimp, could be a good calcium source. Average calcium content of Ngapi is 1 per cent in the product as CaO and the Ca/P ratio is 1 : 5.

Guillerm (10) reported the presence of 687 mg./l. P_2O_5 (300 mg./l. P) in good quality Nuoc-mam. Of the 300 mg./l. P, 275 mg. are in inorganic form. The content of P varies largely with the quality of Nuoc-mam, e.g. 45 mg./l., which has no P in organic form.

Autret and Bouvier (2) gave the following figures for Nuoc-mam: P_2O_5 0·266 g.–0·566 g./l.; CaO 0·439 g.–0·541 g./l.; MgO 2·208 g.–2·310 g./l.

Organic sulfur content of Nuoc-mam varies from 0·54 g. to 1·165 g./l. The proportion of organic nitrogen to organic sulfur is greater in superior quality Nuoc-mam. Average N/S ratio of 10 : 9 was reported for Nuoc-mam containing 10 g./l. of organic nitrogen.

Products with organic nitrogen from 10 g. to 20 g./l. showed N/S ratio of 13 : 5—almost the same as the 13 : 8 N/S ratio in raw fish flesh.

Iron content varies with product, but fermented food prepared from entrails gives a rather high value. Fermented entrails of abalone showed 28 mg. per cent of Fe; 10 mg. per cent for fermented salmon kidney and 13 mg. per cent for the product prepared from entrails of smelt (*Plecoglosus altivelis*).

ADVERSE EFFECTS OF FERMENTED FISH

According to the review by van Veen (44), it has been reported from Indonesia that certain kinds of salted fish (bonito species) become poisonous through the formation of considerable amounts of histamine by the action of certain bacteria. Fish poisonings by ingestion of dried products of sardine and saury, canned mackerel and raw big-eyed tuna were also reported in Japan.

However, food poisoning from fermented fish, such as fish paste or fish sauce, is rarely heard of. There is a record of 700 μg./ml. of histamine detected in a fish sauce kept for 10 years.

Vialard-Goudou's work (45) shows that the amount of indol or related compounds varies from 0 to 400 μg.l. in Nuoc-mam, and β-indol acetic acid may be sometimes present.

The wholesomeness of decomposed fish needs more investigation since, in many cases, half-spoiled fish is customarily used in preparing the fermented product. Kaneda *et al.* conducted animal feeding tests for the hydrolysates prepared from Alaska pollack of three different grades of freshness. The chemical composition of each hydrolysate is shown in Table XXIV.

Three groups of rats averaging 80 g. in weight were given 10 g. basal diet plus 3 ml. of the hydrolysate daily. They were reweighed in a month. The average group weight increase was 35·5 g. on a fresh fish diet, 38·5 g. for rather spoiled fish, and 37·0 g. for drastically spoiled fish. This was despite the hydrolysate of the last group, whose total nitrogen was nearly 50 per cent ammonia nitrogen. These results indicate little possibility of ill-effects from the hydrolysate manufactured from spoiled fish.

Serious poisonings due to *Botulinum* type E have been reported in the northern part of Japan since 1951. These were from home-made fermented fish mixed with cooked rice and fresh vegetables. The way of preparation is almost the same as that practised in other countries of South-east Asia, but a small quantity of salt is used and the procedure of packing the mixture in a closed container may permit the anaerobic condition necessary for the growth of *Clostridium botulinum* type E.

The paucity of information about food poisoning from fermented fish products may be partly due to inadequate organization for collecting reports of cases in far-eastern countries. Therefore, this is not the time to say these products are safe, even though they have been considered free from contamination until now.

THE QUALITY CONTROL PROBLEM

When fermented fish are considered an important animal protein source in South-east Asia, establishment of certain quality controls will become necessary to ensure nutritive value of products before consumption. Fish pastes and sauces particularly need standards, since the true quality of these products can hardly be detected with a layman's eye, owing to the liquid or completely macerated form of the products.

TABLE XXIV

The composition of nitrogenous compounds in the hydrolysates prepared from the fish (alaska pollack) of three different grades of quality

(Kaneda *et al.*, 1950)

Hydrolysate from	*Total nitrogen g./100 ml.*	*Ammonia nitrogen mg./100 ml.*	*NH_3-N T.N. %*	*NaCl g./100 ml.*	*Volatile acid ml. of 0·1 N-NaOH*
Fresh fish	1·280	146	11·4	30·1	9·9
Fish stood for 3 days . .	1·896	263	13·9	32·4	51·1
Fish stood for 10 days . .	1·306	637	48·3	28·0	250·9

2 parts of fish were hydrolysed by 1 part of HCl for 8 hours, and pH value of the hydrolysate was adjusted to 4·9 by NaOH, before feeding. The composition of basal diet was; 77 parts powdered brown rice, 15 parts fish meal, 2 parts McCollum salt, 1 part $CaCO_3$, 5 parts dried yeast, and 1 drop of tuna liver oil. This diet contained 7·86 per cent of crude protein.

At present the Vietnamese fish sauce, Nuoc-mam, may be the only product subjected to government standard quality control. Inspectors use total nitrogen, formol nitrogen and salt content as the main subjects of examination. Minimum requirements for total nitrogen of the fish sauce in Vietnam are 20 g./l., 16 g./l., and 12 g./l. for pure Nuoc-mam, second and third grades respectively. Of the total nitrogen, formol-titrable-nitrogen should contain at least 50 per cent, and ammonia nitrogen should be less than 50 per cent of formol nitrogen.

The need of standards for lower-classed products is important, because it is quite a common practice to leach the fish residue, after the first pickle has been drawn off, in order to increase the yield of Nuoc-mam by a second-quality product.

With some fermented fish pastes, there exists the practice of adulteration by mixing in starch, rice bran or bean peels. Artificial colouring with dyestuffs, possibly carcinogenic or toxic, can be seen in the manufacture of the fermented shrimp, such as Trassi in Indonesia or Bagoong in the Philippines. Proper instruction and control would be required for these cheap manufactures.

Mostly, these traditional products give a peculiar flavour which may be repulsive for those outside South-east Asia or South Africa. However, within the region, this flavour is the most important factor in market value.

Therefore, many difficulties will be encountered if quality control starts simply with hygienic control or with the nutritionist's criticism against the consumer's preference.

Nuoc-mam, for a typical example, is preferred only because it contains a specific Nuoc-mam flavour which could never be attained by an aseptically-maintained autolytic process. An improved method of preparing a new Nuoc-mam by auto-digestion under germ-free conditions was therefore totally unsuccessful.

Another peculiar flavour for which Pedah-Siam is liked was described by van Veen (44), who said the presence of methylketone was essential to evaluate the marketable quality. He reports an interesting correlation between methylketone content and the price of Pedah-Siam.

"Kusaya" is a dried horse mackerel, prepared after splitting and dipping in saturated brine which has been used for many years without renewal except for an occasional addition of salt and shark's head. It is another product with an offensive odour. However, quite a number of consumers still prefer this peculiar dried fish in Japan.

So these decomposition products, including methylketone, volatile acids, volatile basic nitrogen or indol, can hardly be taken as criteria for quality control, although these are undoubtedly developed by spoilage during fermentation.

The decision to fix the standard of nitrogen compounds in a product like Nuoc-mam may be reasonable as a practical quality control method. However, it is said that quality control of Nuoc-mam is not actually worked out in Vietnam.

FUTURE PROBLEMS

In spite of the low consumption rate of fish in South-east Asia or Africa, there still occur seasonal surpluses due to lack of facilities for treating unusually large catches. In this respect, the rôle of fermented fish should be to provide protein through this form of processing, since fermented fish is more highly valued than many other available protein foods.

High salt content may remain an obstacle in encouraging people to eat more products of this type. Refrigeration is one of the solutions for lowering salt content in fermented fish. In Japan, where the fish processing industry is rather developed, Shiokara or some other fermented fish are usually put in cold storage with average temperature of 5°C. In this way the industry can prepare more tasteful products by reducing the salt content. But handling of these lightly-salted fish will offer another difficulty for retailers, namely quick spoilage, if they are not handled at low temperatures during distribution.

Much improvement is possible in preventing loss of nutritive constituents from fermented fish products. For individual products, the optimum fermentation period should be carefully established in each country. Most of these parts of the processing have not received adequate technological research. Unreasonable handling of raw fish, ignorance in use of salt and sub-materials, and laxity in sanitation are points which could be changed immediately, without any need of new research work.

The application of certain mould preparations or refined enzyme preparations may not be introduced immediately. However, it seems worthwhile investigating the possibility of not only replacing slow maceration with more active fermenting agents, but also adding flavour to suit all tastes, thus assuring increased consumption.

For the major items of fermented fish in the region, it is advisable to fix workable quality standards by which the improvement in the quality, and possibly in the nutritive value, can be reasonably expected.

SUMMARY

(1) The various kinds of existing traditional fermented fish products in South-east Asia have been grouped into two categories: the first, products principally macerated by action of fish enzyme; the second, those fermented by the combined effect of fish enzyme and microbial preparations as starters. In addition, the possibility of chemical maceration and the introduction of enriched enzyme preparations into the processing of fermented fish were discussed as a third group.

(2) It was almost certain that product quality in group (I) depended entirely on enzymatic activities derived from raw fish. However, these natural enzymes are generally slow in disintegrating fish protein, except those of the

digestive system and particularly that of the pyloric caeca. For this reason, the use of entrails became significant in product manufacture. There seemed to be some kinds of fish more suitable for fermented products, due to their comparatively high potency of enzyme action.

(3) Addition of salt provided preservative action against bacterial decomposition in processing; a salt content of more than 20 per cent of the product is unusual in commercial fermented fish of this group. However, minimum concentration of salt to keep down ammonia formation should be 20 per cent of product weight. Salt free from impurities is always recommendable for quicker maceration.

(4) The presence of a certain variety of bacteria may be indispensable, since it may give the specific flavour of some particular product. But most salt-tolerant microorganisms surviving in fermented fish will produce ammonia rather than amino acids.

(5) There is scanty information about group (II) products. The major agent seems to be lactic acid fermentation which develops in the mixed cereals. But the significance of fish enzyme cannot be ignored. The amount of lactic acid formed in one product of this type was as high as 7 per cent on a moisture-free basis.

(6) Incorporation of the mould preparation (*Aspergillus oryzae*) will be promising in fish paste preparation, because it may complete fermentation in less time. The importance of fungal action in a commercial preparation of Katsuobushi was noted.

(7) During fermentation in both groups (I) and (II), approximate nitrogen loss may average 30 per cent; but nitrogen loss could be smaller in fish sauce, because there is little drainage. Although sufficient information cannot be obtained, the retention of amino acids was found fairly good in fish sauce and fish paste.

(8) Oil in the fermented fish is of little nutritional value since rancidity development greatly reduces the value in long-term maceration.

(9) B vitamins can be regarded as having minor nutritional significance.

(10) For the acceleration of fermentation, proposals such as the raising of temperature, the use of enriched enzyme, and combination with chemical hydrolysis, may need further research before being applied.

(11) No serious case of fermented fish poisoning has been reported, except for sporadic outbreaks of botulism type E from eating Izushi, a home-made Japanese fermented fish of the group (II).

(12) Need for the establishment of quality control was emphasized from the technological point of view, so that the nutritional value of each product can be reasonably assured.

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APPENDIX I

Varieties of fermented fish, fish paste, and fish sauce in South-east Asia

(Abstracted from *Fisheries Products Manual*)

Country	*Name of product*	*Raw fish majorly used*	*Amount of salt added*	*Period of fermentation*	*Preparation of raw fish*
Burma	Nga-bok-chauk	Threadfin (*Polynemus indicus*) Sea Perch (*Lates calcarifer*)	Not specified, cured after fish allowed to spoil		Head, tail, and belly are separated
	Ngapi	*Barbus stedmanensis*, *Barbus sarana caudimarginata*, *Cirrhina latia*, *Notopterus notopterus*, *Cyprinus carpio*	4 fish : 1 salt	2 days in brine	Whole
	Ngapi (pounded)	Anchovy (*Engraulis commersonii*) Planktonic shrimp	Not specified	Several weeks after salting, pounding and drying for 8 days	
Annam and Cochin-China	Mam-tom	*Spirontocaris gibberosa* M. Edw., *Alhaeus macrochirus* Richters, *Penaeus semisulcatus* de Haan	12 : 1 after 24 hours salting, the shrimps are pressed, and half-dried, then made to a paste, returned to the jar	2 weeks	Whole
Cambodia	Mam-ruoc	Fresh-water shrimps	Not specified	Not specified	Whole
	Pra-hoc	*Ophicephalus micropeltes C.V.* *Ophicephalus striatus* Bl. *Labeo chrysophekadoin* Bl.	10 : 1 salting, pounding and drying are involved in the whole process	1 month, Pra-hoc-youn is a similar product with less salt than ordinary Pra-hoc	Beheaded and eviscerated
India and Pakistan	Hidal knunda	Small fish, not specified	Fish is placed in a hole dug in the ground	1 month	Whole
	Baleechong	Prawns	3 : 1		Whole
	Shidal Sutki				Not specified Whole?
Indonesia (North Borneo)	Bladchan				Whole
	Trassi	Planktonic shrimp (Mysidacea)	Drying, pounding and salting	Not specified	Whole
Indonesia	Trassi-ikan	Small fish, not specified			Whole
Japan	Shiokara	Squid	8 : 1	2 weeks	
		Planktonic shrimps	4 : 1	1 month	
		Small crabs	4 : 1	1–2 months	
		Sea urchin	10 : 1	2 weeks	
		Skipjack entrails	4 : 1	3–4 weeks	
		Sea cucumber entrails	8 : 1	2–3 weeks	
	Kusaya	Horse mackerel	Saturated brine has been kept for repeated use	Few hours dipping, then dry	Split
Malaya	Belachan	Acetes shrimp, Mysid shrimp	100 : 4–5	1 month	Whole
Philippines	Bagoong	Anchovy (*Stolephorus* sp.) Tamban (*Sardinella* sp.) Galonggong (*Decapterus* sp.) Small shrimp (*Atya* sp.) Goby fry, (*Ostrea* sp.) other small fish	3 : 1	3 months to 1 year	Whole
	Tinabal	Fish, not specified	4 : 1, 3 : 1	6–15 months	Whole
	Balbakwa	Fish, 6–10 in.	5 : 1	6–8 months	Whole
	Bagoong tuligan	Fish, head and viscera removed	Less salt than ordinary Bagoong		Whole
	Dinailan	Small shrimp, dried and pounded			Whole
	Guinamos alamang	Shrimp			Whole
	Lamayo	Shrimp			Whole
Thailand	Pla-ra-sod	Fish, beheaded, pounded to remove scales, viscera and fat	2 : 1	3 months	Beheaded and eviscerated
	Kapi	Planktonic and semi-planktonic crustaceans: *Acetes* sp., *Myses* sp., *Copepoda*, *Lacifer*, *Stolephorus* spp., *Rastrelliger* spp.	3–5 : 1	15 days up to 1 year	Whole
	Pla-ra-lao	Small whole fish	Strongly salted		Whole
	Pedah Siam	*Rastrelliger neglectus* Viscera, gill are removed *Decapterus*, *Caranx*	3 : 1		Eviscerated
Africa	Fessik	Grey mullet, Alestes, tiger fish.	Heavily salted	Several months	Whole
Burma	Fish sauce from Ngapi		Not specified	Not specified	
Cambodia	Nuoc-mam-gau-ca	Fish liver from *Clarias* sp., *Ophicephalus micropeltes* C.V.	10 : 1	8 days. Boil and filter after fermentation	Liver

APPENDIX I—*continued*

Country	*Name o, product*	*Raw fish majorly used*	*Amount of salt added*	*Period of fermentation*	*Preparation of raw fish*
Annam	Nuoc-mam	*Stolephorus* spp., *Clupeoides lile* Blkr., *Engraulis mystax*, *Dorosoma nasu* (Bloch), *Decapterus* spp.	3 : 2	3 months to 1 year	Whole
Gulf of Siam	Nuoc-mam ruoc	Shrimps	Not specified	Not specified	Whole
Indonesia (Kalimantan)	Fish sauce	*Clupea*, *Stolephorus*, *Leiognathus* (Brackish-water species) *Osteochilus*, *Puntius*, *Ctenops* (Fresh-water species)	Not specified	6 months to 1 year	Whole
Japan	Uwo-Shoyu	Sardine	3 : 1	6 months	Whole
Korea	Fermented shrimp	Not specified	Not specified	6 months	Whole
Philippines	Patis	*Stolephorus commersonii*, *Stolphorus indicus*, *Clupeoides lile*, *Sardinella perforata*, *Sardinella fimbriata*, *Sardinella longiceps*, *Decapterus macrosoma*, *Leignathus*	3 : 1, 4 : 1	5 months to 1 year	Whole
Thailand and Tonkin	Ca-mam	Fresh-water species	2 : 1, some alcohol and betel leaves are added	2 months	Gutted
Thailand	Nam-pla	*Stolephorus* spp., *Rastrelliger* spp., *Cirrhinus* spp. Heads, gills, and viscera of *Rastrelliger* are also used	5 : 1–1 : 1	5–17 months	Whole
Hong Kong	Fish sauce	*Sphyraena jello*, *Carangidae* spp., *Sardinella aurita*, *Teuthis albopunctatus*, *Engraulis purava*	3 : 1	3–7 months	Whole

APPENDIX II

Varieties of fermented fish products prepared by addition of the starters, such as cooked, roasted rice, mould preparations and miscellaneous stuffs in South-east Asia

(Abstracted from *Fisheries Products Manual*)

Country	*Name of product*	*Raw fish majorly used*	*Amount of salt added*	*Period of fermentation*	*Preparation of raw fish*
Cambodia	Paak (mam-chao)	*Cirrhinus micropeltis* Sauv. *Macrones* sp.	5 : 1–30 : 1 Salted 30 days, then added glutinous rice, angkak, palm sugar, and yeast	3 months after mixing additives	Beheaded and eviscerated
Indonesia (North Borneo)	Pekasam		Cooked rice, cooked glutinous rice also used		Not specified
Japan	Shiokara Funa-sushi	Squid Crucian carp (*Carassius carassius*)	3 : 1–5 : 1 for squid, added moulded cooked rice after 1–2 weeks 1 : 1 for Crucian carp cured for 2 months	1 month for Shiokara, 2 months for Funasushi	Sliced flesh of squid is used Gutted, gonad is not removed for Funasushi preparation
	Izushi	Mackerel, sardine, atka-mackerel, and salmon	Lightly salted, cooked rice, and fresh vegetables added	2–3 weeks	Filleted
Philippines	Buro	Fresh-water fish *Ophicephalus* sp., *Chanos chanos*, martiniko, dwarf gouramy	After salting fermenting rice, salted cooked rice, angkak are mixed	1 week	Dressed
	Balao-balao	Small shrimp, *Ophicephalus* sp.	After salting cooked rice, used, but angkak is not added	1 week	Whole
Thailand	Pla-chom	*Cirrhina* sp., small shrimps	Removal of viscera and scales, salted and added cooked rice	3 days	Scaled and eviscerated
	Pla-chao	*Wallago*, *Belodontichys*, *Kryptopterus*, *Puntius*, *Notopterus*, *Ophicephalus*	After 3 days salting, washed and dried, then mixed with "Kao-mak", fermented glutinous rice by adding yeast and KNO$_3$	1 month	Whole
	Pla-ra	Half-spoiled fish caught by dynamiting in the Maeping river	5 : 1, added boiled rice in 1/2 of fish	6 months	Beheaded and eviscerated

APPENDIX II—*continued*

Country	*Name of product*	*Raw fish majorly used*	*Amount of salt added*	*Period of fermentation*	*Preparation of raw fish*
Cambodia	Mam-ca-sat	*Pangasius*	7 : 1, salted 6–10 days in a jar, then mixed with roasted rice	10 days, it can be stored for several years	Beheaded and gutted
	Mam-ca-loc	*Ophicephalus striatus*	Salted 10–30 days, then mixed with ginger, sugar, pineapple, and roasted rice	5 days after mixing these additives	Beheaded, gutted, scaled and bones are cut off
Indonesia	Makassar fish	*Engraulis* sp. *Stolephorus* sp.	Large amount of salt After few days, added angkak, ragi and spices	Not specified	Beheaded
Borneo	Wadi	Fresh-water fish	Salted, added roasted rice or maize	Not specified	Not specified
Thailand	Pla-mum	*Ophicephalus striatus*, *Ophicephalus micropeltis*	Salted and added by roasted rice 3–6 months. Take out and mix with sliced pineapple or honey	Not specified	Beheaded, gutted, scaled and sliced
	Pla-ra	*Trichogaster*, *Cirrhina*	Heavily salted for 2 days–3 months, then mixed with rice bran or roasted, milled rice	3 months–1 year	Beheaded and gutted
	Kung-chao	Fresh-water and marine shrimp	Same as Pla-chao		Remove scale and entrails
	Pla-ra-kao	*Labeo* sp., *Trichogaster* sp., *Kryptopterus* sp., *Clarias* sp. Small fresh-water fish	Fish allowed to spoil before salting for 12–14 hours, then mixed with roasted rice	1–2 months	Not specified
Laos	Padec	Similar to Pra-hoc. Place in basket for 3 days after gutting and slicing, then pound with salt. Drain off, pickle for 2–3 days, pounded again with salt and rice husks	Salt content of the product is about 1 per cent	Not specified	Beheaded, gutted and sliced
Ceylon	A wet cured fish	Not specified	Placed in saturated brine, add 2 per cent of *Garcinia camboges* by weight of fish	2–3 months	Not specified
India	Colombo-curing	Mackerel, sardine, and seer (*Cybium* sp.)	3 : 1, along with salt, a variety of tamarind (*Garcinia camboges*) is mixed	Can be stored for 1 year	Gutted and gills removed
India and East Pakistan	Dried, powdered fish	Small fish	Stored in hole dug in the ground for 1 month. Then dried, powdered, and made into ball with crushed stem of *Caladium*	Not specified	Not specified
Cambodia	Mam-ruot	Entrails and flesh of *Ophicephalus micropeltes*, *Ophicephalus striatus*, *Pseudosciaena* sp.	Not specified	Not specified	
	Mam-seing	Eggs of lake fish *Ophicephalus micropeltes*, *Ophicephalus striatus*	6 : 1, mixed with roasted rice	5–6 months	

In Africa, as well as in South-East Asia, the need for protein is so great that a taste has been developed for fermented fish. Here is shown a large consignment packed in petrol cans produced at a canning shop on the banks of the Nile, Sudan.

THE INFLUENCE OF SOLVENT EXTRACTION ON THE NUTRITIVE VALUE OF FISH PROTEIN

by

A. B. MORRISON

A brief description of different processes used in production of fish flour is given, and various studies are reported on the nutritive value of the protein in fish flour prepared by different processes. From the results of the latter, it is evident that at least some procedures do not uniformly result in products of good nutritional value. Considerable variability in nutritional value was observed, due to the use of different extraction procedures.

In comparing the therapeutic effects of a maize diet supplemented with 10 per cent casein (casilan), 10 per cent South African fish flour or 10 per cent VioBin fish flour respectively, it was evidenced that neither type of fish flour was as suitable as casein. Better results are reported with isolated soybean protein supplemented with methionine and glycine than with VioBin fish flour on the growing rate of chicks. Little definite information exists on the effects of solvents on the nutritive value of fish protein; there is, therefore, a great need for properly controlled experiments to compare critically the effects of various solvents on the composition and nutritive value of fish flour.

From the biochemical point of view, studies should be carried out on the possibility that toxic products may be produced by reactions between fish solids and solvents, solvent decomposition products or solvent impurities. From the technical point of view, studies are needed on the influence of processing variables on the nutritive value of fish flour. At present time, it does not appear possible to state definitely either that any particular process or solvent will always result in a flour of good quality or that any particular process or solvent always yields a poor quality flour. A better understanding of the biochemistry and technology of fish flour is necessary before the material can take its place as an important source of high-quality protein in underdeveloped areas of the world.

L'INFLUENCE DE L'EXTRACTION AU SOLVANT SUR LA VALEUR NUTRITIVE DES PROTEINES DE POISSON

On donne ici une brève description des différents procédés de fabrication de la farine alimentaire de poisson, et l'on expose diverses études sur la valeur nutritive des protéines dans les farines alimentaires préparées selon différents procédés. D'après les résultats de ces études, il est évident que quelques procédés au moins n'aboutissent pas d'une façon régulière à des produits de bonne valeur nutritive. On observe une grande variabilité dans le valeur nutritive, due à l'emploi de différentes méthodes d'extraction.

D'une comparaison des effets thérapeutiques d'un régime de maïs supplémenté respectivement avec 10% de caséine (Casilan), 10% de farine alimentaire de poisson sud-africaine ou 10% de farine alimentaire de poisson VioBin, on a constaté qu'aucun type de farine de poisson ne convenait aussi bien que la caséine. On a signalé, à l'égard du taux de croissance des poulets, des résultats supérieurs avec des protéines isolées de soja supplémentées avec de la méthionine et de la glycine qu'avec de la farine alimentaire VioBin. Peu d'informations sûres existent sur les effets des solvants à l'égard de la valeur nutritive des protéines de poisson; il est donc nécessaire d'effectuer des expériences convenablement contrôlées pour comparer d'une façon critique les effets de divers solvants sur la composition et la valeur nutritive de la farine alimentaire de poisson.

Du point de vue biochimique, il faudrait étudier l'éventualité d'une production de composés toxiques par les réactions qui interviennent entre les solides du poisson, les solvants, les produits de décomposition des solvants ou les impuretés des solvants. Du point de vue technique, il serait nécessaire d'effectuer de plus amples recherches sur l'influence des variables du traitement à l'égard de la valeur nutritive de la farine alimentaire de poisson. Pour l'instant, il ne semble pas possible d'affirmer définitivement qu'un procédé ou qu'un solvant donné va toujours conduire à une farine alimentaire de bonne qualité, ni qu'un procédé ou un solvant donné ne produira jamais qu'une farine de mauvaise qualité. Une meilleure connaissance de la biochimie et de la technologie de la farine alimentaire de poisson est nécessaire avant que ce produit puisse prendre sa place comme source importante de protéines de haute qualité dans les pays sous-développés du monde.

EFECTO DE LA EXTRACCION POR SOLVENTES EN EL VALOR NUTRITIVO DE LA PROTEINA DE PESCADO

Se describen brevemente diversos procedimientos de preparar harina de pescado y se informa de varios estudios sobre el valor nutritivo de la proteína de la harina fabricada de diferentes maneras. De los resultados de los últimos se desprende que por lo menos algunos procedimientos no dan productos de valor nutritivo uniformemente bueno. Se han observado grandes variaciones en el valor nutritivo debido al empleo de diferentes métodos de extracción.

Al comparar los efectos terapéuticos de una alimentación de maíz con complementos de un 10% de caseína (Casilán), un 10% de harina de pescado sudafricana, o un 10% de harina de pescado VioBin, se ha puesto en evidencia que ninguna de ellas es tan conveniente como la caseína. Se comunican resultados mejores con proteína de soja aislada con complementos de metionina y glicina, que con harina de pescado VioBin en la velocidad de crecimiento de pollos. Existe poca información concreta sobre los efectos de los solventes en el valor nutritivo de la proteína de pescado y, por lo tanto, es muy necesario efectuar experimentos perfectamente regulados para comparar críticamente los efectos de diversos solventes en la composición y valor nutritivo de la harina de pescado.

Desde el punto de vista bioquímico se debería estudiar la posibilidad de que se produzcan compuestos tóxicos por reacción entre sólidos y solventes de pescado, productos de la descomposición de solventes o impurenzas de éstos. Desde el punto de vista técnico, será necesario efectuar estudios de la influencia de las variables de la elaboración en valor nutritivo de la harina de pescado. De momento, no parece ser posible afirmar que un procedimiento o solvente dados darán siempre por resultado una harina de buena o mala calidad. Un conocimiento mejor de la bioquímica y de la tecnología de la harina de pescado son necesarios antes de que este producto pueda ocupar su puesto como fuente importante de proteína de alta calidad en los países subdesarrollados del mundo.

POSSIBILITIES for increasing the supply and consumption of fish depend upon many factors, including scientific management of fish resources and technological advances in distribution and preservation (1). Widespread use of fresh or canned fish is, in general, not economically feasible in many technically underdeveloped countries. More traditional methods of preservation, such as smoking, salting or drying, have been widely used, but fish so processed does not have a long storage life, especially under tropical conditions. Recently, several processes have been developed, by which fresh fish or good quality fish meal can be treated to remove the moisture, lipid and odor, yielding a stable, tasteless and odorless "flour" containing 70–90 per cent protein. If desired, the deodorization step can be omitted for population groups that prefer a fishy taste in their foods. The processes used for production of fish flour all involve treatment of fish solids with organic solvents such as hexane, the lower alcohols or chlorinated hydrocarbons. Possible effects of solvent extraction on the nutritional value of the protein in the resultant flour have not received much attention, and it has generally been assumed that fish flour is consistently of high biological value. It is the purpose of this report to review briefly available information on the effects of solvent extraction on nutritive value of fish protein.

It would seem appropriate in a review such as this to discuss processes currently used in production of fish flour. In the Guttmann-Vandenheuvel process (2), washed fresh offal, consisting of the trimmings from filleting tables (excluding the heads), from fish such as cod, haddock and hake is heated with dilute polyphosphoric acid to 75–78°C for 30 minutes. The slurry is filtered and the resulting press-cake washed with hot water, and refluxed for 15 minutes with isopropanol. The slurry is again filtered, and the fat and moisture-free press-cake screened to remove skin and bones, dried under reduced pressure and ground. The yield is 10 pounds of flour, containing 94–98 per cent protein on a dry, ash-free basis, per 100 pounds of offal. The Dabsch process involves azeotropic extraction of fresh fish or fish meal with petroleum ether, followed by deodorization by means of repeated washings with ethanol. This process is basically that used in the pilot fish flour plant supported by UNICEF in Chile (3). Another process, the Vogel process, is notable primarily as a deflavoring and deodorizing procedure. Fat-free material is treated with acid or alkali, plus organic solvents, and the resultant product is dried at reduced temperature (3). The VioBin process has been described by Levin (4, 5). Briefly, it involves azeotropic extraction with ethylene dichloride. Deodorization is then carried out by extraction with methanol or ethanol. Other procedures have also been used for preparing edible fish flour, notable among which is the Fishing Industry Research Institute (FIRI) process used in South Africa, which involves ethanol extraction of good quality fish

TABLE I

Nutritional value of casein or defatted fish flour fed at three different levels to growing male rats for 4 weeks

Data of Morrison and Campbell (7)

	Casein			*Fish flour*		
	Diet 1	*Diet 2*	*Diet 3*	*Diet 4*	*Diet 5*	*Diet 6*
Diet protein, per cent	7	10	15	7	10	15
Weight gain, g.	53 ± 10[1]	99 ± 17	152 ± 21	106 ± 9	148 ± 10	162 ± 13
Protein efficiency ratio, g. gain/g. protein	2·86 ± 0·81	3·04 ± 0·30	2·74 ± 0·21	4·19 ± 0·35	3·80 ± 0·19	2·71 ± 0·16
Liver weight, g. Adjusted[2]	6·37	6·50	7·23	6·65	7·14	6·77
Kidney weight, g./pair Adjusted	1·18	1·28	1·43	1·23	1·26	1·47
Adrenal weight, mg./pair Adjusted	24·3	24·9	20·6	22·6	26·2	25·5
Liver lipids, per cent	5·02 ± 0·62	4·50 ± 1·07	5·67 ± 1·18	5·50 ± 1·15	5·14 ± 0·64	5·47 ± 0·80

[1] Standard deviation. [2] Adjusted by covariance analysis for differences in body weight.

TABLE II

Effect of fish flour (FF) on the nutritional value of white bread, as measured in growing male rats fed diets containing 10 per cent protein for 4 weeks

Data of Morrison and Campbell (7)

	Diet 1 *Casein*	*Diet 2* *Bread*	*Diet 3* *Bread + 10% FF*	*Diet 4* *Milk bread*	*Diet 5* *Milk bread + 10% FF*
Weight gain, g.	109 ± 14[1]	23 ± 8	145 ± 16	43 ± 10	130 ± 13
Protein efficiency ratio, g. gain/g. protein	3·49 ± 0·14	1·30 ± 0·21	3·87 ± 0·13	1·97 ± 0·27	3·59 ± 0·18
Liver lipids, per cent	5·48 ± 0·30	8·38 ± 0·87	6·17 ± 1·04	9·20 ± 2·10	6·30 ± 1·15
Liver cholesterol, mg./g. wet tissue	2·50 ± 1·38	3·71 ± 0·57	2·86 ± 0·89	2·94 ± 1·18	2·13 ± 1·31

[1] Standard deviation.

meal, followed by vacuum drying, with steam stripping to remove residual solvent (6).

Most of the processes used appear to yield products of high nutritional value. Morrison and Campbell (7, 8) have studied the nutritional value of the protein in fish flour prepared by the Guttman-Vandenheuvel process. The material used was prepared from cod, and was a fat-free grayish powder containing 90 per cent protein. In one experiment, groups of male weanling rats were given otherwise adequate diets containing 7, 10 or 15 per cent protein supplied by fish flour or casein. As shown in Table I, protein efficiency ratio (PER) values found after 4 weeks for 7 per cent and 10 per cent fish flour were significantly higher than those for comparable levels of casein; but similar values were found for both proteins at the 15 per cent level. The source of dietary protein had no significant effect on liver, kidney or adrenal weights, although renal hypertrophy was observed in animals given 15 per cent protein.

In additional studies, the effects of the above-mentioned sample of cod flour on the nutritional value of white bread were examined. Four samples of enriched white bread were prepared according to a common bread recipe. Two of the samples contained 4·2 per cent milk solids, whereas water was used in making the other two samples. Prior to baking, 10 per cent of cod flour was added to one of the samples made with milk and to one of those made with water, at the expense of white flour. The baked samples were air-dried, ground and fed to groups of male weanling rats at the 10 per cent protein level in an otherwise adequate diet. PER values found after 4 weeks are summarized in Table II. Addition of fish flour to bread, made with or without milk, increased the PER values by 82 per cent and 198 per cent respectively, and significantly reduced liver lipid levels. The effects of fish flour on PER values could be explained on the basis of its contribution of lysine to the diet.

TABLE III

Nutritive value of protein in fish flour produced by VioBin process
Data of Metta (9)

Diet	*Protein efficiency ratio*	*Biologic value*
	g. gain/g. protein	%
Fish flour . . .	3·24 ± 0·10[1]	88 ± 2·6
Whole egg . . .	3·56 ± 0·08	97 ± 1·9

[1] Standard deviation.

Metta (9) determined the nutritional value of the protein in a sample of fish flour produced by the VioBin process, using growth and nitrogen balance procedures. As shown in Table III, in pair-fed rats the PER value of fish flour was 90 per cent of that found for whole egg. The biological value of fish flour protein, determined by the classical balance sheet method of Mitchell, was 88 per cent, whereas that of whole egg was 97 per cent.

The nutritional value of a sample of deodorized fish flour was determined by Miller (10), who used the net protein utilization (NPU) method of Miller and Bender (11). The sample was produced in South Africa, but the process used was not that of the FIRI, according to Dreosti (12). The NPU value was found to be 67, significantly less than that found for cod protein preparations produced in the laboratory by solvent extraction with acetone. In South African studies (6) the net protein utilization (biological value × digestibility) of fish flour produced by the FIRI process was found to be 66 per cent, whereas those of VioBin fish flour and whole egg protein were 72 per cent and 89 per cent, respectively. No evidence was obtained that the FIRI fish flour contained any toxic substances.

Allison *et al.* (13) conducted an extensive series of studies on the nutritional value of fish flour produced from hake meal by the Dabsch process. The flour was tested in growing rats by adding it at various levels to a protein-free diet, and adjusting the total dietary protein to approximately 25 per cent by adding casein. To test for possible toxic effects, the animals were maintained on experiment from weaning to one year of age. Blood cytology, organ weights and histopathology of various organs were studied at intervals during the experiment. The results showed that substitution of fish flour in various concentrations for casein did not significantly influence the gain per gram of food consumed. Cytological and histopathological studies failed to indicate any deleterious effects of fish flour. In further studies, it was observed that fish flour fed at two protein levels had equivalent PER values to those found with similar levels of casein. Similarly, nitrogen balance index measurements in dogs indicated that the protein in the sample of fish flour was similar to milk protein in its ability to maintain nitrogen equilibrium in the adult dog.

Bender (14) determined the NPU values of a number of samples of fish flour prepared either from fish meal or fresh fish by the Dabsch process. A flour made from fresh cod fillets gave an NPU of 64, whereas a sample made from fresh whole herring gave a value of 73.

Various samples of solvent-extracted fish flour prepared in the laboratory have also been studied and found to be of good nutritional value. Alcarez-Bayan and Leverton (15, 16) prepared flour from the dilis fish, an anchovy abundant in Philippine waters. Raw fish flour was made by drying the whole fish under the sun and grinding. The raw flour was then extracted with three or four batches of boiling ethanol, and dried at low temperature to produce a deodorized flour. The amino acid composition of the protein was closely comparable to that reported in the literature for casein, whole egg, beef muscle and other varieties of fish. Both raw and deodorized dilis flour contained protein of quality comparable to that of casein, as determined by growth and nitrogen balance procedures.

Miller (10) prepared cod flour by extracting cod flesh with acetone and air drying to allow evaporation of residual solvent. In one study, the NPU value was found to be 79·5. In a second experiment, however, the value for a sample prepared by the same procedure was only 68·3.

From the above-mentioned results, it might appear that fish flours are of uniformly high nutritional value. However, not all investigators have found fish flour to be of high quality, and there is evidence that at least some procedures do not uniformly result in flours of good nutritional value. As reported by FAO (3), Bender found NPU values of various samples of fish flour to vary from 29 to 77. Digestibility coefficients varied from 68 to 96 per cent. It is not possible, from the data presented, to separate the effects of processing conditions from those of species of fish and other factors.

Morrison and McLaughlan (17) observed considerable variability in nutritional value of samples of fish flour prepared by various extraction procedures. Five samples were studied. Sample A was prepared from cod and haddock fillets by azeotropic extraction of the raw material with ethylene dichloride, followed by deodorizing with ethanol. Sample B was prepared from a mixture of cod, herring, hake, shark and ray, by solvent extraction of the raw material. No information was available on the solvent used. Sample C was prepared from whole menhaden by extraction of the raw material with tertiary butanol. Samples CC and CH were prepared from cod and herring offal, respectively, by isopropanol extraction according to the procedure of Guttmann and Vandenheuvel (2). As shown in Table IV, corrected PER values varied from 1·51 (sample A) to 2·76 (sample CH). The two samples prepared by the Guttmann-Vandenheuvel process had PER values which were similar and comparable to that found with the flour prepared by tertiary butanol extraction.

TABLE IV

Variability in nutritional value of fish flour

Data of Morrison and McLaughlan (17)

	Experiment 1				*Experiment 2*		
	Casein	*Fish flour A*	*Fish flour B*	*Fish flour C*	*Casein*	*Fish flour CC*	*Fish flour CH*
Weight gain, g.	59±10[1]	23±4	50±8	66±9	63±7	64±9	75±10
Protein efficiency ratio, g. gain/g. protein							
Unadjusted	2·92±0·30	1·78±0·20	2·51±0·31	3·05±0·26	2·88±0·13	3·01±0·23	3·23±0·23
Adjusted[2]	2·50	1·51	2·13	2·59	2·50	2·58	2·76
Liver lipids, per cent	4·20±0·55	3·33±0·59	4·20±0·64	4·07±0·57	3·91±0·35	4·02±0·51	3·99±0·28

[1] Standard deviation. [2] Adjusted to a standard value of 2·50 for casein.

Other workers have also found that certain samples of fish flour are of relatively poor nutritional value. Pretorius *et al.* (18) gave convalescent kwashiorkor patients a maize diet supplemented with 10 per cent casein (casilan), 10 per cent South African fish flour or 10 per cent VioBin fish flour. The therapeutic effects of the three diets were compared by following weight gains, serum albumen concentration, and nitrogen balance, as well as the clinical condition of the patients. The results indicated that the diet containing South African fish flour was unsuitable in many cases for the treatment of convalescent kwashiorkor. There was some evidence that the sample of VioBin flour was more satisfactory, but neither type of fish flour was as suitable as casein. Recently, Zeigler and Scott (19) reported that chicks given a purified diet containing VioBin fish flour grew significantly less rapidly than those given a similar diet containing isolated soybean protein supplemented with methionine and glycine. Repeated washing of the fish protein with water at pH 4·7 and/or the addition of various sources of chick unidentified growth factor supplements failed to improve growth. Isonitrogenous addition to the fish diet of 10 per cent isolated soybean protein increased weight gains by approximately 18 per cent.

In other investigations, Kurtzman *et al.* (20) conducted chemical analyses and rat and chick assays to study variability in the quantity and quality of the protein of fish flours currently or potentially available on the world market. These workers concluded that fish flour "can neither be considered to have a given protein content nor to be a consistent source of high quality protein". Most of the nine samples tested by Kurtzman *et al.* contained protein of good or excellent quality, but PER values ranged from 1·20 to 2·78.

Although the results of several of the above-mentioned studies suggest that the solvent used in preparing fish flour may have an important effect on its nutritional value, little work has been done to compare critically the effects of different solvents. In most instances, definite conclusions cannot be drawn from published data because of differences in pre-processing handling of the fish, species of fish, time of year, or other processing factors. Such factors must be carefully controlled, if meaningful results are to be obtained.

We have recently, however, had occasion to examine the nutritional value of samples of fish flour prepared from whole redfish (ocean perch), redfish fillets or redfish gurry, by the Guttmann-Vandenheuvel process or by azeotropic extraction with ethylene dichloride (21). The pre-processing history of the samples was identical, as far as could be ascertained. The samples were fed to groups of male weanling rats at the 11·5 and 23 per cent protein level, in otherwise adequate diets. Net protein ratios (NPR) were determined after one week by the method of Bender and Doell (22) and PER values were calculated after 3 weeks. The results indicated that, when tested at the 11·5 per cent protein level, the three samples prepared by the Guttmann-Vandenheuvel process were of higher nutritional value than those prepared by azeotropic extraction with ethylene dichloride. The apparent difference between the two processing methods was not observed, however, when the samples were tested at the 23 per cent protein level. Samples produced with ethylene dichloride contained less lysine and methionine than those produced by the Guttmann-Vandenheuvel process, but the ratio of "available" lysine to total lysine was not influenced. Flour produced from fillets was of greater nutritional value than that produced from gurry.

The nutritional value of these flours was also determined by Kurtzman *et al.* (23). These investigators used both rats and chicks to examine the materials, and found that, when fed to rats at the 9 per cent protein level, samples produced by the Guttmann-Vandenheuvel process were of greater nutritional value than those produced by extraction with ethylene dichloride. In general, digestibility of the protein was not significantly influenced by the process used, and it was concluded that the differences observed were related to the utilization of the protein after absorption. However, when the chick was used as the test animal, the situation was reversed; samples produced by azeotropic extraction with ethylene dichloride were of somewhat greater nutritional value than those produced by extraction with isopropanol. As Kurtzman *et al.* (23) pointed out, the difference between species of test animal may be related to differences in requirements for amino acids or unidentified growth factors.

We have also studied the nutritional value of samples prepared from cod, herring, rosefish and caplin by a modification of the Guttmann-Vandenheuvel process (21). The modification involved removal of bones by chloroform flotation, rather than by screening. When tested at the 10 per cent protein level, the samples were of good nutritional value, but when tested at the 20 per cent protein level, they inhibited growth and food consumption, indicating the presence of a toxic factor. The toxicity was directly related to the organic chloride content of the samples, and, although it could be removed by ether extraction, was resistant to removal by prolonged heating.

There is also evidence from work with other proteins that prolonged solvent extraction may reduce the nutritional value. Harris and Mattill (24) extracted liver and kidney globulins with boiling ethanol for several days, and observed a significant decrease in the amount of free amino nitrogen, although the amount of total nitrogen was not affected. Other dehydrating solvents, including methanol, acetone and isopropanol produced similar effects. These workers suggested that during extraction free amino groups (principally from lysine) were combined with carboxyl, imino or hydroxyl groups into new enzyme-resistant linkages. De Muelenaere *et al.* (25) prepared zein from corn gluten by alcoholic extraction, and found that the method of preparation reduced the availability of threonine and valine, as measured by a rat growth assay. *In vitro* and *in vivo* digestion studies showed that the alcoholic treatment reduced the digestibility of zein.

In an extension of the work of Harris and Mattill (24), we have recently examined the effects on lysine availability of prolonged extraction of cod flesh with isopropanol (26). Cod fillets were chopped, air dried and refluxed with twice their weight of isopropanol for 2, 4, 12 or 24 hours. The slurry was filtered hot, and the resultant press-cake was washed with two volumes of hot isopropanol. The press-cake was then air-dried; ground and residual solvent was removed *in vacuo.* Total amino N was determined by the procedure of Melnick and Oser (27), after *in vitro* digestion of the samples with pancreatin. Availability of lysine was determined by a rat growth assay, using a modification of the method of Calhoun *et al.* (28). The results showed that the amount of total amino N released from the samples by pancreatic digestion *in vitro* was not influenced significantly by the isopropanol treatment. Availability of lysine in the samples was also not affected by the prolonged extraction.

In an extensive series of studies on changes in stored herring meals, Lea *et al.* (29) found that cod muscle reacted rapidly with propanal, resulting in a decrease in total free amino groups, in "available" lysine and in nutritive value as measured by chick bio-assay. It was concluded that aldehydic decomposition products of oxidizing fat can rapidly destroy "available" lysine under conditions similar to those existing in fish meal during storage. Oxidized herring meal contained more lipid apparently "bound" to protein than did fresh meal. The "bound" lipid was much more resistant to solvent extraction than the great bulk of the fat. Whether or not reactions analogous to those studied by Lea *et al.* (29) can occur in fish flour, or whether some samples of fish flour (particularly those made from fish meal) contain "bound" lipid is not known. Although it should be pointed out that not all fish flours are completely fat-free, it would appear unlikely that the amount of lipid in most samples is sufficient to exert significant effects on nutritional value.

From the aforementioned results, it is obvious that there is little definite information on the effects of solvents on the nutritional value of fish protein. There is a great need for properly controlled experiments to compare critically the effects of various solvents on the composition and nutritional value of fish flour. Such studies should include investigations of the basic biochemical reactions involved. Studies should be conducted to investigate the possibility that the deleterious effects of feeding high levels of certain samples may be caused by binding of toxic solvents to protein. The possibility that toxic products may be produced by reactions between fish solids and solvents, solvent decomposition products or solvent impurities also needs further investigation.

The problem of reduced availability of amino acids in certain samples of solvent-extracted fish flour is of particular importance and should be studied extensively. It is possible that samples containing unavailable amino acids may have been heated too rigorously during removal of the solvent, and that poor quality samples produced from fish meal may have undergone heat damage during curing of the meal. Studies need to be conducted also on the most efficient solvent for extracting lipid and water from fish solids, since the solvents now being used for these purposes are not all equally effective. For example, hexane is known to be a poor solvent for protein-bound lipid, which consists largely of phospholipids.

From a technological rather than biochemical point of view, it is necessary that careful studies be conducted on the effects of processing variables, including the solvent used, on the nutritional value of fish flour. At the present time, it does not appear possible to state definitely that any particular process or the use of any given solvent will always result in a flour of good quality. Conversely, it is not known definitely that any particular process or solvent always yields a poor quality flour. A better understanding of the biochemistry and technology of fish flour is necessary before the material can take its place as an important source of high-quality protein in underdeveloped areas of the world.

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THE INFLUENCE OF IRRADIATION PRESERVATION ON THE NUTRITIVE VALUE OF FISH AND FISHERY PRODUCTS

by

J. M. SHEWAN

Fish and fishery products were among the first foodstuffs to be tested by the irradiation preservation technique. Of the many products that have now been examined, none has stood up to the doses necessary for commercial sterility, mainly because of the production of undesirable odour, flavour and colour changes.

Pasteurization, particularly in conjunction with so-called "combination techniques" such as the use of antibiotics, antioxidants and blanching, appears to be much more promising, and most of the research work now in progress is confined to this aspect of the technique.

Even with pasteurization, however, it is clear that there are considerable differences in the results obtained, depending mainly on the species or type of food irradiated. In general, fatty fish give much less satisfactory products than non-fatty species, owing to the development of rancid and other off-flavours in the fats and lipid components, while in species such as salmon and tuna the pigment is either destroyed or so altered as to make the product unacceptable in appearance.

On the other hand some products, such as blanched oysters, cod, lemon sole, smoked cod and cooked crab meat, stand up well.

The type of container (whether plastic or tin, etc.), the presence or absence of oxygen or of an inert gas such as nitrogen, and the temperature of the foodstuff during irradiation, all affect the suitability of the product for irradiation.

Pasteurizing doses can generally effectively reduce the bacterial load, particularly on the raw products, and consequently there is often a considerable extension of the shelf life of the product at chill or room temperatures as compared with the controls. However, there are various discrepancies in the extension times claimed by various workers; but these are almost certainly due to the different organoleptic standards used. Anyhow, on the basis of such extensions, many believe that by the use of irradiation the market for certain fish and fishery products could be considerably expanded.

Nutritionally, fish in general are looked upon as being valuable sources of proteins, minerals and certain vitamins such as thiamine, niacin and vitamin A. All the available evidence seems to show that irradiation, even at much higher doses than those used for pasteurization, does not seriously impair the food value of the fish flesh. Moreover, feeding trials and other data so far have shown no indication of any toxic or carcinogenic component being present in irradiated fish flesh.

L'INFLUENCE DE LA PRESERVATION PAR IRRADIATION SUR LA VALEUR NUTRITIVE DU POISSON ET DES PRODUITS DE LA PECHE

Le poisson et les produits de la pêche sont parmi les premières denrées alimentaires à avoir été soumises à la technique de préservation par irradiation. Parmi les nombreux produits qui ont été dès maintenant étudiés, aucun n'a été porté aux doses nécessaires pour obtenir la stérilité industrielle, en raison principale de l'apparition d'une odeur indésirable et de modifications de saveur et de couleur.

La pasteurisation, en particulier en conjugaison avec les techniques dites "combinées" qui mettent en oeuvre des antibiotiques, des antioxydants et le blanchiment, apparaît plus riche de promesse; et la plus grande partie du travail de recherche actuel se confine dans cet aspect de la technique.

Même dans le cas de la pasteurisation, il est cependant clair qu'il existe des différences considérables dans les résultats obtenus, en fonction surtout de l'espèce ou du type d'aliment irradié. En général, le poisson gras donne des produits bien moins satisfaisants que les espèces non grasses, par suite du développement d'un goût de rance et d'autres saveurs désagréables dans les graisses et les composants lipidiques, tandis que chez certaines espèces comme le saumon et le thon, le pigment est détruit ou altéré de telle manière que le produit devient inacceptable par son aspect.

D'un autre côté, quelques produits comme les huîtres blanchies, la morue, la limande sole, la morue fumée et la chair cuite de crabe se comportent bien.

Le type du récipient, (c'est-à-dire plastique ou étain, etc.), la présence ou l'absence de l'oxygène ou d'un gaz inerte tel que l'azote et la température de la denrée alimentaire durant l'irradiation affectent tous la convenance du produit à cette irradiation.

Les doses de pasteurisation peuvent en général réduire efficacement la charge bactérienne, en particulier dans les produits bruts; en conséquence, elles permettent souvent une extension considérable de la durée de conservation du produit à des températures froides ou ambiantes, par comparaison avec des échantillons témoins. Cependant, divers auteurs ne sont pas d'accord en ce qui concerne les durées de cette extension de la conservation, mais ce désaccord est certainement dû à la différence des normes organoleptiques appliquées. Quoi qu'il en soit, en tenant compte de telles extensions, certains pensent qu'avec l'emploi de l'irradiation on pourrait élargir d'une façon considérable les débouchés de certains poissons et produits de la pêche.

Sur le plan de la nutrition, le poisson est généralement considéré comme une source de valeur pour les protéines, les minéraux et certaines vitamines telles que la thiamine, la niacine et la vitamine A. Toutes les données disponibles semblent montrer que l'irradiation, même à des doses plus hautes que celles utilisées pour la pasteurisation, ne change pas sérieusement la valeur alimentaire de la chair de poisson. En outre, les essais d'alimentation et autres données n'ont pas jusqu'ici révélé aucune indication de la présence de composant toxique ou cancérigène quelconque dans la chair irradiée de poisson.

EFECTO DE LA PRESERVACION POR IRRADIACION EN EL VALOR NUTRITIVO DEL PESCADO Y LOS PRODUCTOS PESQUEROS

El pescado y los productos de la pesca se encuentran entre los primeros alimentos sometidos a la técnica de preservación por irradiación. De los muchos productos que se han examinado, ninguno ha resistido las dosis necesarias para obtener la esterilidad industrial, debido principalmente a modificaciones del color y a la aparición de olores y sabores desagradables.

La pasteurización, particularmente junto con las técnicas llamadas de combinación, como el uso de antibióticos, antioxidantes y escaldado, parece ser mucho más prometedora y por esto casi todas las investigaciones que se realizan actualmente se circunscriben a este aspecto de la técnica.

Sin embargo, aun con la pasterización es evidente que existen enormes diferencias en los resultados obtenidos, que dependen principalmente de las especies o tipo de alimento irradiado. En general, el pescado graso da productos mucho menos satisfactorios que el magro, debido a la aparición de un sabor rancio y olores desgradables en las grasas y en los compuestos lipídicos, en tanto que en especies como el salmón y el atún el pigmento se destruye o se altera de tal manera que el producto se hace inaceptable por su aspecto.

Por otro lado, productos como las ostras escaldadas, bacalao, lenguado, bacalao ahumado y carne de cangrejo de mar cocida resisten bien el tratamiento.

El tipo de recipiente, (si es plástico u hojalata, etc.), la presencia o ausencia de nitrógeno o de un gas inerte como el nitrógeno, y la temperatura del alimento durante la irradiación, todos influyen en la conveniencia del producto a ser irradiado.

Las dosis de pasterización pueden, en general, reducir eficazmente la carga bacteriana, en particular en los productos crudos; por tanto, a menudo se prolonga considerablemente la duración del producto enfriado o a la temperatura ambiente, con respecto a las muestras testigo. Empero, diversos autores no están de acuerdo en lo que concierne a la prolongación, pero este desacuerdo es casi seguro que se debe a las diferentes normas organolépticas aplicadas. Sin embargo, teniendo en cuenta tales extensiones, muchos creen que aplicando la irradiación se podrá lograr una gran ampliación de los mercados para ciertos pescados y productos de la pesca.

Desde el punto de vista de la nutrición, el pescado se considera en general como una valiosa fuente de proteína, minerales y ciertas vitaminas como tiamina, niacina y vitamina A. Todos los datos disponibles parecen demostrar que la irradiación, aun a dosis muy superiores a las empleadas para la pasterización, no altera gravemente el valor alimenticio de la carne de pescado. Además, los ensayos de alimentación y otros datos no han demostrado hasta ahora que en la carne del pescado irradiado existan compuestos tóxicos o carcinógenos.

FISH were among the first products to be tested when irradiation in its present form was introduced as a preservation technique by Brasch and Huber in 1947 (6). It was an attractive method inasmuch as it afforded the opportunity of controlling microbial spoilage, without using heat or chemical additives. Moreover, since micro-organisms are much more radiation-sensitive (29) than the tissue enzymes (36), it was possible to compare the effects of autolysis alone with those caused by microbial and tissue enzyme actions combined (22, 27). For example with fish, many of the microbial types involved in spoilage—*Pseudomonas* and *Achromobacter* spp.—are completely inactivated by doses of from 2 to 3 M rads (32) (see Table I), whereas even at 14 M rads the apyrase muscle system is only half inactivated (24). As data accumulated, however, it soon became clear that the early promise of furnishing acceptable products likely to compete effectively with other commercially available foodstuffs was going to be hard to fulfil. Subsequently, there were other complicating factors. Doubts were expressed as to the wholesomeness of some irradiated foods; they were said to contain poisonous components or to be radioactive, although, as will be mentioned later, these objections appear to be completely unjustified. Moreover, the suspension in 1959 of the building of the U.S. Army's Ionizing Radiation Center in California, designed to produce about 2 tons of irradiated foods per hour, seemed to support these suspicions.

However, more recent results (including some obtained with certain sea foods) have given rise to a new wave of optimism, particularly in the U.S.A. As was pointed out in 1959 (12, 14) extreme pessimism about the prospects of the irradiation method was hardly justified; for, although sterilising irradiation had yielded unacceptable products in civilian markets, low-dose (or pasteurizing) irradiation, particularly if combined with other procedures such as the use of antioxidants or antibiotics, had been found to hold out promise of considerable improvement. Consequently, it was suggested that concentrated, fundamental, chemical, biochemical and microbiological studies were required in order to define more clearly the technical limits and possibilities of the new process, and such studies have been undertaken in many centres since 1959.

The most recent results suggest that considerable progress has been made towards obtaining products of acceptable eating quality, particularly by using pasteurizing procedures. "Know-how" has been accumulating about ways of minimizing flavour and odour changes (e.g. irradiation of the food in the frozen state); about the use of additives to prevent undesirable flavour and odour changes; and about the use of suitable conditions for storing the irradiated product. Some very recent data obtained at the Torry Research Station for a variety of sea foods confirm the impression that some of these alterations in technique have yielded some products much more acceptable than their counterparts in our earlier experiments.

However, in comparing the large amount of data now available on irradiated sea foods, there still appear to be wide discrepancies in the results obtained by various workers; and in trying to account for this, three facts must be borne in mind.

(1) Sea foods comprise a large variety of products differing from each other not only in appearance, colour, flavour and texture, but also in chemical and biochemical characteristics. It is clear, therefore, that it is almost impossible to generalize. For example, the treatment giving a worthwhile preservative effect with cod fillets is quite unsuitable for salmon, owing to bleaching of the pigment.

(2) In assessing the effect of irradiation, either immediately after treatment or during storage, reliance is nearly always put on organoleptic assessment, and here arises one of the major difficulties. Most frequently a hedonic scale is used, and it is evident from the published data that quite different standards are being used by various workers. The standards of inland consumers are likely to be very different from those of consumers on the sea coast. Moreover, a variety of cooking procedures are being used (frying, baking, steaming in casserole, etc.) and it is well recognized that a product acceptable when fried in deep fat might be quite unacceptable when steamed.

(3) The usefulness of a particular irradiation technique is frequently expressed in terms of "extension of limit of edibility"; this can be quite a misleading criterion. A more suitable one would be "storage life as a good edible product". After all, the success of the method

will depend not on whether it can increase the supply of poor quality products in areas where similar products of poor quality preserved by other techniques, (e.g. chilling or freezing), are already available, but whether it can supply better ones.

A market feasibility study of irradiated fishery products recently carried out by the U.S. Fish and Wildlife Service (1) showed that many in the fishing industry believed irradiation would revolutionize the fresh fish trade, lead to the development of new markets and the expansion of old ones. Canning, it was pointed out, often involves over-cooking the product and anyhow produces something quite different from the fresh article, while freezing produces undesirable changes in texture and flavour. Many of us who have had some experience with both irradiated and frozen fishery products believe that where freezing, and particularly cold storage conditions are properly controlled, the products are usually superior to irradiated ones. In Britain the more progressive firms now use cold storage temperatures for sea foods of −20°F, whereas in the U.S.A. the normal temperature is about −5°F and even higher. Experience at the Torry Research Station and elsewhere has shown that most sea foods held at this latter temperature for any length of time, rapidly deteriorate in organoleptic quality; it is not surprising therefore that it is considered in the U.S.A. (1) that irradiation could compete successfully with freezing.

As the Market Feasibility study pointed out, if irradiation is to become commercially feasible it must fulfil a useful purpose at an economic cost and the products must be wholesome and nutritionally adequate. So far as irradiated pasteurized products are concerned, the advantages likely to accrue are: reduction in spoilage losses, extension of the marketing period, maintenance of quality during marketing and accessibility of untapped markets. Such advantages, it is believed, could also be claimed for freezing, were it to be properly carried out. However, it is the opinion of many experts in the U.S.A. that the products which hold out the best technical promise for low dose irradiation are some sea foods and fruits, and at the moment a most intensive programme is under way or is about to commence on the irradiation pasteurization of 4 specific sea foods (haddock, flounder, crab and clam). These studies are to include the determination of shelf life at various pasteurizing dosages, nutritional value and wholesomeness, the most suitable packaging material and consumer acceptance. The results, when available, should make the comparison between irradiation and other modern methods of preservation a much easier proposition.

1. Radiation at sterilizing doses

Reports from a variety of sources show that most fishery products can be near-sterilized by doses of about 2·0 M rads (35). This is perhaps not surprising since pure culture studies have shown that many of the bacterial types involved in the spoilage of sea foods, e.g. *Pseudomonas* spp.—are quite sensitive to irradiation (9, 32, 37) (Table I). However, to produce a commercially safe product, doses of 5·0 M rads are required, in order to ensure the destruction of the spore bearer *Cl. botulinum* (9). Such a treatment does not cook the fish, the rise in temperature being at the most only about 10°C, but it does so alter their organoleptic properties that they are quite unacceptable to the consumer (7). Table II shows the maximum permissible irradiation doses that can be given to various sea foods. Doses in excess of these values produce undesirable organoleptic changes in odours, flavours or appearance. These undesirable

TABLE I

Irradiation of some freeze-dried species from National Collection of Marine Bacteria with 100 Krad

[Teär, (37)]

NCMB No.	*Species*	*Number of bacteria/ml. broth* *Before*	*After irradiation*
1	*Photobacterium splendidum*	1·6 10^4	10^3
4	*Serratia marinorubra*	2·2 10^9	3·7 10^7
5	*Corynebacter erythrogenes*	5·0 10^9	8·1 10^6
6	*Vibrio anguillarum*	1·0 10^6	10^3
7	*Photobacterium phosphoreum*	1·4 10^5	10^3
10	*Pseudomonas fluorescens*	5·6 10^9	2·9 10^4
13	*Micrococcus* sp.	3·7 10^{10}	8·1 10^9
14	*Micrococcus* sp.	5·0 10^{10}	1·1 10^{10}
21	*Flavobacterium* sp.	1·0 10^9	7·1 10^7
22	*Flavobacterium* sp.	3·0 10^6	2·1 10^5
126	*Pseudomonas* sp.	3·0 10^5	10^3
128	*Pseudomonas* sp.	5·0 10^9	4·7 10^6
132	*Achromobacter* sp.	1·0 10^9	1·0 10^8
135	*Achromobacter* sp.	5·6 10^9	1·0 10^9
23	*Pseudomonas formicans*	1·5 10^9	9·0 10^4
30	*Pseudomonas olevorans*	1·2 10^8	9·0 10^4
38	*Spirillum* sp.	3·2 10^8	1·4 10^5
40	*Spirillum* sp.	2·4 10^7	10^2
127	*Pseudomonas* sp.	2·2 10^9	1·8 10^6
136	*Pseudomonas* sp.	3·0 10^9	2·8 10^6

TABLE II

Maximum irradiation dose for acceptability of sea foods

Reference	*Species*	*Irradiation treatment*	*Maximum irradiation dose for acceptability* *M rads*
Carver and Steinberg (1959)—see Proctor *et al.* (28)	Whiting	Raw fillets	0·23
Proctor *et al.* (28)	Whiting	Raw fillets	0·25
	Silver Salmon	Frozen steaks under vacuum	0·50
Nickerson *et al.* (23)	Haddock fillets	Cellophane wrap in air	0·60
Carver and Steinberg 1958—see Proctor *et al.* (28)	Haddock	Raw fillets	0·70
	Butterfish	Raw fillets	0·70
	Pollack	Raw fillets	0·70
Proctor *et al.* (28)	Pollack	Raw fillets	0·75
	Butterfish	Raw fillets	0·75
	Flounder	Raw fillets	0·75
	Salmon	Smoked, frozen	0·75
	Sturgeon	Smoked, frozen	0·75
	Tuna	Smoked, frozen	0·75
	Petrale Sole	Fillets frozen	0·75
	Halibut	Steaks frozen in cans	0·75
	Salmon steaks	Pre-cooked breaded	0·75
	Ocean Perch	Frozen—vacuum	0·75
	Ocean Perch	Frozen—blanched	0·75
	Cod	Raw in tins in air	1·0
Carver and Steinberg (1958)—see Proctor *et al.* (28)	Cod	Raw fillets	0·83
Proctor and Bhatia (1958)	Haddock	Fillets in polythene in air	0·90
Carver and Steinberg (1958)—see Proctor *et al.* (28)	Pollock	Blanched 5 mins. 60°C	0·93
	Whiting	Blanched 5 mins. 60°C	0·93
	Ocean Perch	Blanched 5 mins. 60°C	0·93
Proctor *et al.* (28)	Mackerel	Frozen in cans under vacuum	1·0
	Mackerel	Blanched 5 mins. 100% frozen	1·0
	Haddock	Frozen under vacuum	1·0
	Haddock	Blanched 5 mins. 100°C under vacuum	1·0
	Pollack	Fillets blanched 5 mins. 60°C	1·0
	Whiting	Fillets blanched 5 mins. 60°C	1·0
	Cod fillets	Raw	1·0
	Cod fillets	Frozen	1·0
	Haddock	Smoked—skinned fillet	1·5
	Black cod	Smoked—frozen	1·5
	Cod	Smoked—steamed	1·5
	Cod	Fillets blanched 5 mins. 60°C	1·9
	Butterfish		1·9
	Cod	Fillets blanched 5 mins. 60°C	2·0
	Butterfish	Blanched	2·0
	Herring	Kippered	2·0
	Cod	Fish sticks—pre-cooked	2·0
	Haddock	In cans, frozen	2·25
	Lobster	Boiled, tail and claw	0·25
	Oregon Shrimp	Picked, fresh	0·25
	Lobster meat	Cooked in polythene bags	0·5
	Crabmeat	Picked, cooked	0·5–1·0
	Crabmeat	Picked, frozen	0·5
	Oysters	Breaded, frozen, pre-cooked	0·5
	Crabmeat	Frozen	0·75
	Alaska Shrimp	Frozen	0·75
	Shrimp	Breaded, frozen, pre-cooked	0·75
	Oysters	Smoked and heat processed	1·0
	Clams	Heat processed	1·0
	Oysters	Smoked in cans under vacuum	1·0
	Soft shelled Clams	Smoked	1·5
	Oysters	Raw shucked	5·0
	Crabmeat	Cooked frozen cakes	6·0

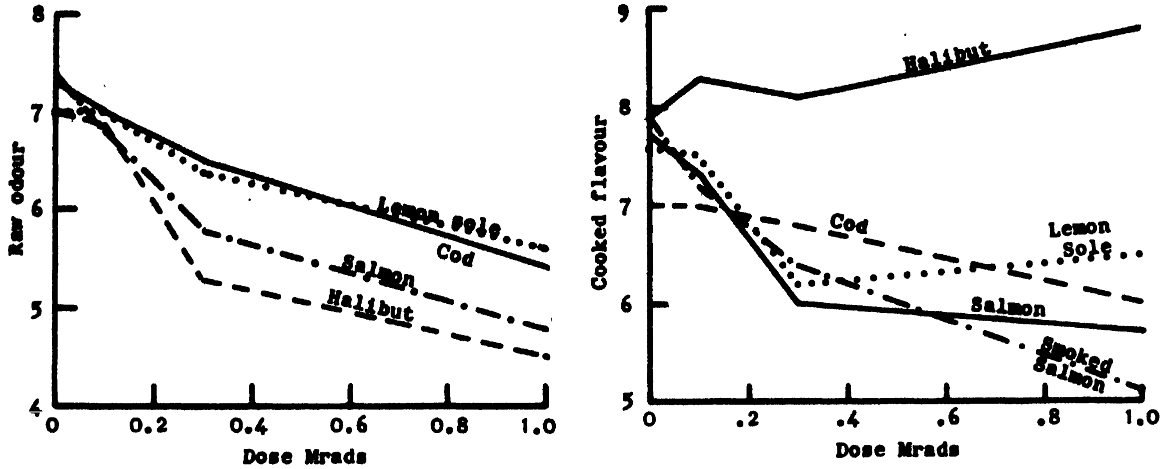

Fig. 1. The effect of irradiation on the initial organoleptic assessment of various species of fish.

odours and flavours, which have been described as "metallic", "burnt feather-like", "rubbery", "salt fishy" and so on, can, of course, be detected after irradiation at levels much lower than those given in Table I, but usually do not become objectionable until the dose levels reach the values quoted in Table II. It will be noted that species such as whiting, haddock and lobster are extremely sensitive to irradiation, while tuna, smoked fish, fish sticks, blanched oysters and cooked crab meat are relatively quite resistant. Some recent data obtained at the Torry Research Station in conjunction with the Low Temperature Research Station at Cambridge (England) endorse these findings (Fig. 1).

The conclusion seems to be unavoidable that, until some means have been devised that can improve considerably the organoleptic properties of the majority of sea foods listed in Table II, sterilization by irradiation will not be a feasible commercial proposition. Some such means may be irradiation in the frozen state or in the presence of inert gases; the use of chemical protectors (11) and the choice of suitable packaging materials (17).

2. Pasteurization

Whilst sterilization appears, therefore, to be of little more than academic interest, the development of a satisfactory technique of pasteurization seems to be a more readily attainable objective. So far as fish are concerned, most of the work now in progress, particularly in various Department and Research Institutes in the U.S.A., is

TABLE III

Sensory assessment of fish irradiated with cathode rays
[Coleby and Shewan (7)]

Type of Fish	0 *Rads* Control		$0{\cdot}5 \times 10^6$ *rads* Unfrozen		$0{\cdot}5 \times 10^6$ *rads* Frozen		$3{\cdot}5 \times 10^6$ *rads* Unfrozen		$3{\cdot}5 \times 10^6$ *rads* Frozen	
					Raw Odour Scores					
	T[1]	*C*[2]	*T*	*C*	*T*	*C*	*T*	*C*	*T*	*C*
Haddock	6·9	5·3	6·1	4·7	7·0	4·5	5·0	2·0	5·0	4·0
Cod	8·0	6·7	5·8	3·1	7·7	5·7	5·1	3·0	5·7	3·7
Ling	7·9	5·4	7·3	4·8	6·9	4·8	5·4	2·2	5·6	2·8
Lemon Sole	8·0	5·5	7·0	3·8	6·6	4·7	5·2	3·7	4·9	3·5
Mackerel	7·0	6·5	5·5	3·8	5·5	5·8	5·0	1·8	5·7	4·6
Herring	6·9	5·6	6·3	4·4	6·3	5·0	5·5	2·8	4·6	4·2
Kipper	7·3	5·7	6·3	4·3	6·7	3·3	4·6	2·5	5·0	5·0
					Cooked Flavour Scores					
	T	*C*	*T*	*C*	*T*	*C*	*T*	*C*	*T*	*C*
Haddock	7·4	6·2	5·8	4·5	6·2	4·7	2·5	2·0	4·5	3·7
Cod	7·2	6·3	6·8	6·5	7·1	4·0	3·8	3·8	4·3	4·3
Ling	6·4	5·6	4·9	4·8	5·3	5·0	2·5	3·4	3·4	3·6
Lemon Sole	7·3	5·6	5·9	5·4	7·0	4·8	3·9	3·4	4·0	4·2
Mackerel	6·1	6·2	4·5	5·0	5·8	3·1	4·3	2·4	4·1	4·2
Herring	6·6	7·0	4·5	4·2	5·8	4·6	4·1	2·2	4·2	3·8
Kipper	7·1	4·8	5·7	3·8	6·4	5·4	4·6	3·6	4·9	4·8

[1] *T* = Torry Research Station panel scores of 4·5 and under = inedible, 10 = fresh.
[2] *C* = Low Temperature Research Station, Cambridge panel scores of 4·0 and under = inedible, 9 = very palatable.

attempting to find (1) the species or products more suitable for this treatment; (2) the maximum dose consistent with acceptable quality; and (3) the shelf life at temperatures between 0° and 5°C. In addition, in attempts to improve organoleptic properties and storage life, pasteurization is being combined in some instances with processes such as enzyme inactivation, e.g. by blanching at say 60° or 100°C for 5 minutes; irradiation in the frozen state, and the addition of antibiotics, antioxidants or chemical protectors.

Irradiation in the frozen state often substantially diminishes "off" odours and flavours. This is well illustrated in Table III for a variety of sea foods which were irradiated raw, frozen and unfrozen, at levels of 0·5 and 3·5 M rads. In nearly every instance the frozen fish gave a more acceptable product, organoleptically, than the unfrozen ones. Blanching also allows the irradiation doses to be increased considerably (see Tables II and IV), without impairing acceptability; antibiotics combined with irradiation add considerably to shelf life (17, 34); while antioxidants not only retard the development of rancidity on storage, but also prevent to some extent the bleaching of the pigment in some species such as salmon (Farber, personal communication).

TABLE IV

The effect of blanching on the irradiation dosage limits
[from Bender, Miyuchi and Carver (4)]

Species	*Raw fish fillets rads*	*Blanched (140°F for 5 min.) fish fillets rads*
Cod	$0{\cdot}93 \times 10^6$	$1{\cdot}86 \times 10^6$
Pollack	$0{\cdot}40 \times 10^6$	$0{\cdot}93 \times 10^6$
Butterfish	$0{\cdot}70 \times 10^6$	$1{\cdot}86 \times 10^6$
Whiting	$0{\cdot}23 \times 10^6$	$0{\cdot}93 \times 10^6$

Some of the data available on the extension of the shelf life of sea foods, through irradiation mainly at pasteurizing levels and stored at chill temperatures, are given in Table V. It will be noted that the extensions range from 7 days for pollack and ocean perch to over 215 days for "finnan haddies". It will also be noted that there are considerable differences in the results obtained with the same or similar species by the different laboratories. As mentioned earlier this seems almost certainly due to differing standards of acceptability used, which make proper comparisons difficult, if not impossible.

The extensions of shelf life are due in large measure to reductions in bacterial loads as a result of irradiation (see, e.g. Table VI). Detailed analysis of the bacterial flora, both before and after irradiation and during storage at chill temperatures, seems to show that pasteurization not only reduces the load but also has a marked selective action in the various groups normally present (19, 34). In particular the pseudomonads, known to be active in fish spoilage, are virtually eliminated (34).

3. Nutritional value

(*a*) **Introduction.** As has been pointed out by Read (30, 31), Kraybell *et al.* (15) among others, the wholesomeness of an irradiated food will depend not only on its nutritional adequacy, but also on its potential toxicity, the latter depending upon the formation of toxic or carcinogenic compounds during irradiation or upon induced radioactivity. It is now generally agreed that with the exposure likely to be used in food processing, there is no danger of foodstuffs becoming radioactive.

At present a most intensive programme of research on the nutritional adequacy and potential toxicity of irradiated foods is being pursued in the U.S.A., involving over 30 research organizations. The first results of some of this work are now being published, so that within the next few years we should be much better placed with regard to these problems than we are at present.

It is not proposed in this paper to consider the data available regarding toxicity—a subject lying outside the competency of the present writer. It could just be added, however, that from the data available relating specifically to sea foods there is no evidence that they contain any toxic products as a result of the irradiation process.

Fish and other sea foods are important nutritionally in supplying protein; lipids; certain vitamins, such as A or D, thiamine, riboflavin; and minerals. It will be useful, therefore, to examine briefly the effect of irradiation on these individual components and then to consider the data available where the nutritional status has been examined by direct feeding experiment.

(*b*) **Proteins.** Amino acids, in pure solution, are known to undergo deamination, decarboxylation, and the breaking of the benzene ring in acids, as trytophan, phenylalanine and tyrosine (9, 26). In proteins, however, they appear to be protected from extensive radiation damage, although some of the changes they undergo may affect their biological value to a significant degree, particularly when a sensitive amino acid is limiting as, e.g. cystine in milk (30). Haddock muscle, irradiated at levels of 0·9, 2·7 and 5·7 M rads, and in which 10 amino acids (arginine, histidine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine and cystine) were estimated microbiologically before and after irradiation showed, with even the highest dose, losses of only 5·0–9·8 per cent (26). Similar results have been obtained with shrimp (39). The biological value of a number of other irradiated proteins, (beef, bean, milk, etc.) has shown little change as a result of irradiation (Fig. 2), certainly no greater than occurs on canning. Anyhow, as Read (30) points out, these small changes in the proteins would be masked during the feeding of a mixed diet of irradiated foods.

(*c*) **Lipids.** Many of the more objectionable organoleptic changes in irradiated foods are said to occur in the lipid fraction—mainly in the glyceride fats and oils (9); but the extent of these changes depends very much on the radiation sensitivity of the oil. Thus, Astrack *et al.* (3) found that while herring oil had merely bland, mild

TABLE V

Storage life of irradiation products at chill temperatures

Authors	*Species*	*Treatment during Irradiation*	*Irradiation Doses*	*Extension of Storage Life*	
			M rads	days at	°F
Nickerson *et al.* (23)	Haddock	Fillets, in cellophane in air	0·6–0·7	42	34–40
	Haddock	Fillets, frozen, vacuum	0·75	39–49	36–40
	Haddock	Frozen, blanched 5 mins. 212°F, vacuum	0·75	49–63	36–40
Boston Lab. Mass.[1]	Cod	Fillets, raw	0·25	94	35
	Cod	Fillets, raw	0·50	31	35
	Cod	Fillets blanched 5 mins. 60°C	0·5	118	35
Fish. Tech. Seattle[1]	Pacific cod	Fillets, raw, in cans in air unfrozen	0·25	56	32
			0·75	112	32
			0·50	108	40
			0·20	70	35
			0·10	46	35
Fish (Food Tech.)[1]	Pacific cod	Fillets, raw	0·46 or less	42	32–35
Boston Lab. Mass.	Pollack	Fillets, raw	0·25	21	35
			1·00	7	35
	Butter fish	Fillets, raw-drawn	0·25	49	35
			0·50	49	35
	Butter fish	Fillets, blanched	0·25	38	35
			0·50	38	35
			0·07	38	35–42
Lerke, Farber and Huber (17)	Sole	Fillets, raw in can at °C	0·27	21	
Fish. Tech. Seattle[1]	Petrale Sole	Fillets, frozen	0·25	35	35
			0·75	70	35
MIT[1]	Ocean perch	Fillets, frozen-vacuum	0·75	28	36–40
		Fillets, frozen-blanched	0·75	7–56	36–40
Fish. Tech. Seattle[1]	Silver Salmon	Steaks, frozen-vacuum	0·25	14	40
MIT	Mackerel	Steaks, frozen-cans-vacuum	0·5–1·0	35–56	40
	Mackerel	Steaks, blanched 5 mins. 212°F frozen vacuum	0·25–1·0	77–128	36
Boston Lab. Mass.[1]	Finnan Haddie	Fillet, skinned	0·75	215	35
			1·50	215	35
	Kippered herring	Whole	0·25	151	35
			2·0	141	35
Fish. Tech. Seattle[1]	Cod-fishsticks	One cooked	0·5	56	35
			1·2	28	75
Boston Lab. Mass.[1]	Lobster meat	Boiled tail and claw	0·25	166	35
			0·50	166	35
MIT[1]	Lobster Meat	Cooked in polybags	0·50	28	32–40
College Park	Crabmeat	Cooked cakes, frozen	0·5	60	35
	Crabmeat	Picked frozen	0·5	60	32
	Blue crab	Cooked and picked	0·75	90	35
	Oysters	Raw shucked	6·00	90	35
	Soft shelled clams	Shucked	0·50	119	35
			1·50	119	30
Lerke, Farber and Huber (17)	Cooked crabmeat and shrimp	In tin at 32°F	0·05–0·25	271	38
Amano and Yamada (2)	Tuna			Control	Irradiated
	Mackerel			(Days at 2°–4°C)	
	Sea bass	Fillets in polythene unfrozen. Ord. temp. steamed	Approx. 1	0–10	40–50
	Conger eel				
	Plaice				
	Prawn	Peeled		0–10	10–20
	Squid Octopus			0–10	0–10
	White Clam	Shelled			
	Baby Clam Oyster	Shelled		0–10	0–10
	Abalone			0–10	50

[1] All quoted by Proctor *et al.* (28)

TABLE VI

Reduction in the bacterial load in fish muscle immediately after irradiation
(expressed as Log No. per g. muscle)

Reference	*Species of fish*	*Unirradiated controls*	*After irradiation doses of*						
			0·1	*0·2*	*0·25*	*0·4*	*0·5*	*0·6*	*1·0 M rads*
Shewan (35) . . .	Haddock Fillets	5·5				2·5		1·75	
	Cod Fillets	5·6	4·0	2·0					
	Cod Fillets	6·3			2·7		2·0		Sterile
			After irradiation doses of						
			0·07	*0·14*	*0·25*	*0·46*	*0·50*	*1·0*	*2·0 M rads*
MacLean and Welander (19)	Cod Fillets	5·7	3·6	2·6	2·0	1·3			
	Cod Fillets	6·5					1·7	0·7	0·2
			After irradiation doses of						
			0·1	*0·2*	*0·23*	*0·46*	*0·70 M rads*		
Miyauchi (21b) . . .	Cod Fillets	5·7	4·6	3·0	2·0	1·3	1·0		
					After irradiation doses of				
					0·25	*1·0*	*2·0 M rads*		
Miyauchi (21a) . . .	Precooked breaded fish sticks	2·4			1·5	<1·0	<1·0		

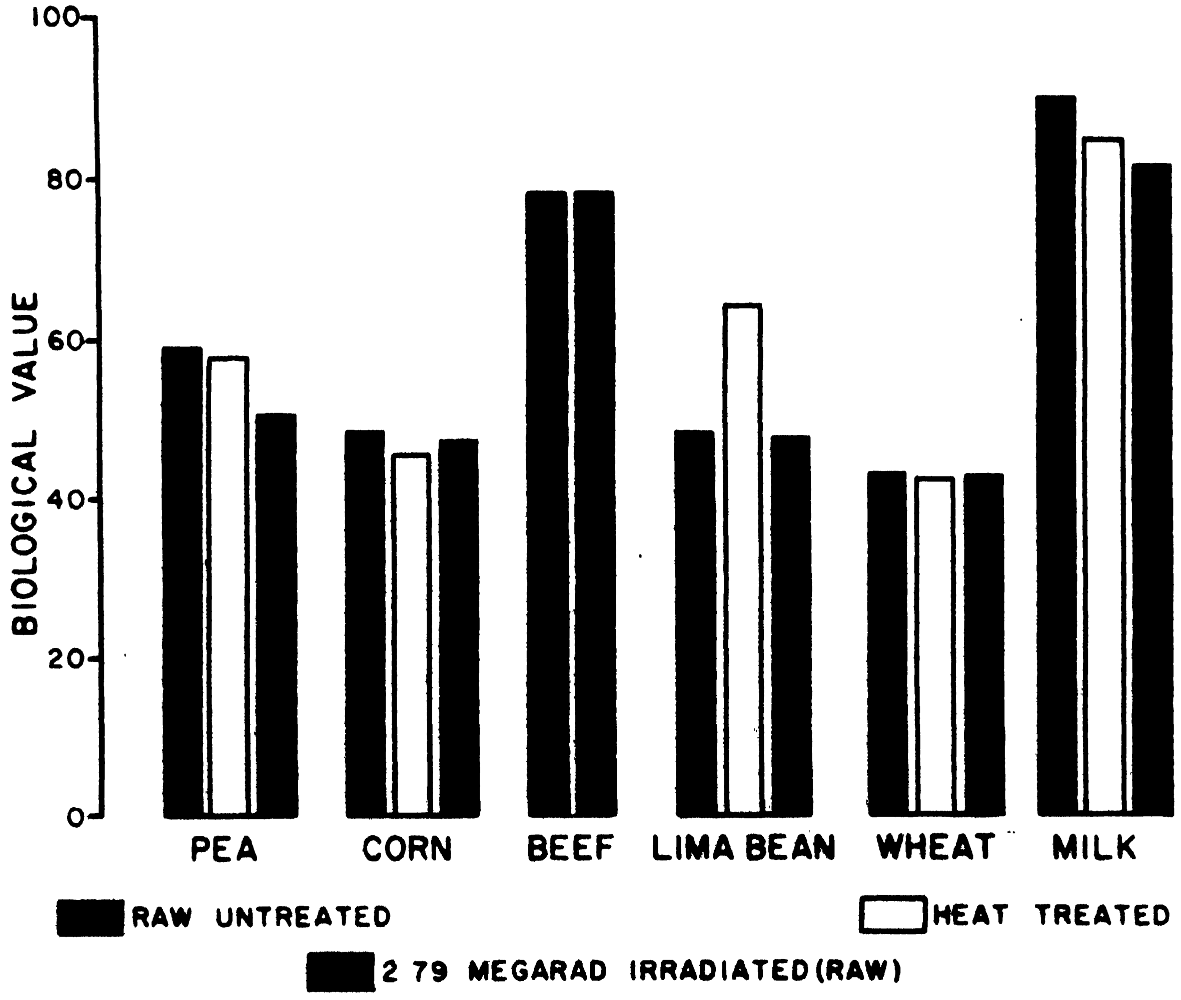

Fig. 2. Biological value of proteins treated with heat or ionizing radiations [from Read (30)]

Table VII

Vitamin destruction due to irradiation of various foods

Reference	*Food*	*Vitamin percentage destruction in food* *Thiamine* *2·79 M rads*	 *Thiamine* *5·58 M rads*	 *Riboflavin* *2·79 M rads*	 *Riboflavin* *5·58 M rads*	 *Niacin* *2·79 M rads*	 *Niacin* *5·58 M rads*	 *Pyridoxin*	 *Pantothenic acid*	 *Folic acid*
Read (30)	Bacon	—	93	—	7	—	0			
	Beef	76	85	5	4	2	1			
	Haddock	68	76	0	4	14	9			
	Ham (fresh)	87	96	0	0	2	2			
	Turkey	76	77	27	50	7	0			
	Beef	52	75	14	10	0	10			
	Milk (powdered)	0	0	0	0	35	20			
	Peaches	94	98	0	0	48	56			
	Shrimp					*4·6 M rads*				
Thomas and Galloway (39)	Enzyme inactivated sealed cans under vacuum	55·6		5·0		51·6		87·5	70	33
	Boiled sealed in cans under vacuum	61·6		0		37·3		81	65	33
	Canned (not irradiated)	72·0		0		72·5		50	50	33
						Thiamine only				
		0	*0·2*	*0·5*	*1·0*	*2·4*	*4·0*	*M rads (over N_2)*		
Groniger, Tappel and Knapp (8)	Salmon	0			54	84	97			
	Halibut	0			86	94	100			
	Tuna	0	21	36	63	89	96			
	Chicken	0			39	58	83			
	Pork	0			61	74	89			

odours and flavours, cotton seed oil and caster oil had ketonic odours and burnt metallic flavours. Oxidative changes, generally believed to be the more important ones produced by irradiation, are acknowledged to be rather complex, involving polymerization, bond breakage, peroxide and carbonyl formation, and so on. As with proteins, in the natural foods the extent of these changes is smaller than might have been anticipated from pure studies. There is, however, some evidence to show that the rate of digestion of lipids is somewhat impaired by irradiation, but even so the net nutritive value appears to be little altered (30). In none of these experiments were fish fats or oils used, but, had they been, there is no reason to believe that the results would have been markedly different.

(*d*) **Vitamins.** While proteins and fats appear to be little altered by irradiation, the situation is somewhat different with regard to vitamins. Most of the water soluble vitamins are quite radio-sensitive particularly in pure solution, thiamine being the most sensitive and niacin the least. However, the sensitivity of the vitamins to irradiation is considerably reduced in the foods themselves, presumably due to the presence of protective compounds. Moreover, the percentage reduction for any particular vitamin varies markedly from food to food (Table VII).

From Table VII it will be noted that at sterilizing doses of 2 or more M rads, most of the thiamine is destroyed, particularly in sea foods; indeed its destruction appears to be the greatest single change in nutritional value in the irradiation sterilization of meat and fish products. On the other hand riboflavin is comparatively

Table VIII

Percentage destruction of vitamin A in samples of oil irradiated at various levels
[from Hata and Oniski (10)]

Dosage in M rads	*Fish liver oil* *Without antioxidant*	 *With antioxidant* *N.D.G.A.*	 *With antioxidant* *B.H.T.*	 *With antioxidant* *Vit. E*	*Synthetic vit. A (alcohol in olive oil)*	*Synthetic vit. A (palmitate in olive oil)*
0	0	0	0	0	0	0
0·216	5·7	3·0	1·0	1·1	11·9	2·0
0·44	8·7	12·6	2·2	1·1	19·6	9·1
1·04	9·3	12·5	8·6	7·4	26·4	22·0
1·88	11·5	14·6	15·9	6·3	36·1	22·5

stable although, as with thiamine, there are often large differences between individual foods. [Cf. beef and haddock (thiamine) and turkey and haddock (riboflavin).] Niacin is generally more sensitive than riboflavin and, if the data for shrimp with regard to pyridoxine, pantothenic acid and folic acid are at all typical for sea foods, these compounds also suffer considerable losses on irradiation. Recent results for beef, however, indicate that pyridoxine suffers only 25 per cent reduction, and niacin, folic acid and choline none at all.

With regard to the fat soluble vitamins, they are generally more sensitive to irradiation than the majority of water soluble ones. Vitamin A and carotene are extremely sensitive both in pure solutions and in foods. Thus in milk 30 per cent of vitamins A and E are destroyed by 0·08 M rads, and 60–70 per cent by 0·5 M rads, although this destruction is somewhat less in butter and margarine (33). Twenty-five per cent of the tocopherol in meat is destroyed at a dose of 4·8 M rads and any present in fish would probably suffer similar losses (5). However, some recent work with vitamin A in fish liver oil and synthetic vitamin A in olive oil (both in the ester and alcohol form) shows that up to 1·9 M rads the vitamin A in fish liver oil suffers little loss (10) (Table VIII). It will also be noted from this table that various antioxidants offer some protection against irradiation damage.

There appear to be no data available regarding the effect of irradiation on vitamin D in sea foods, some of which are particularly rich in this vitamin. But certain biological evidence with growing chicks would indicate that it also suffers some loss during irradiation (33).

In general it may be concluded that irradiation (even at pasteurizing levels) may cause serious losses in the vitamins naturally occurring in foods, although these are no greater than occurs during canning (see Table IX). Such losses are not likely seriously to detract from the irradiation process as such, since they could be made good from suitable natural or artificial sources.

TABLE IX

Comparative effects of radiation and heat treatments on vitamin contents of foods
[from Read (30)]

Vitamin	*Percentage destruction* *Heat*	 *Irradiation (2·79 M rads)*
Thiamine	60–70	55–65
Riboflavin	18–22	6–10
Pyridoxin	28–32	24–25
Niacin	30–35	0–14
Choline	?	0
Folic Acid	35	0
Inositol	?	0–5
Vitamin A	20	31–70[1]
Vitamin E	?	61[1]

[1] Dosage = 0·44 M rads in dairy products

(*e*) **Feeding experiments.** So far we have been dealing with the changes undergone by some of the nutritionally important components of foodstuffs as a result of irradiation. It will be useful now to look at some of the data for the nutritional status of foodstuffs which have been examined by direct feeding experiments.

As mentioned previously, some early writers have thrown some doubts on both the nutritional adequacy and wholesomeness of irradiated foods (14); and as a consequence a most extensive series of experiments is now going on in the U.S.A. using 24 foods, including at least four sea foods, viz. cod, salmon, tuna and shrimp (30).

Some of the experimental work has yet to be completed; but it is clear that, when all the data are published, a much clearer picture of the status and wholesomeness of irradiated foods will be available than hitherto. In some of this work the effect of irradiation on the nutritional value of proteins is being evaluated by the conventional methods of determining digestibility and biological value by the method of Mitchell (20), while the wholesomeness is being assessed by the method described by Lehman and Laug (16). This involves long-term feeding of at least 3 species of animals—one of which must not be a rodent—with the determination of growth rate, reproductive capacity and histopathological examination of major organs, blood, etc.

Some of the more important facts that have now emerged from the already published data may be briefly summarized as follows:

The metabolizable energies derived from protein (casein), fat (lard), and carbohydrate (mixture of sucrose, dextrin and starch in ratio of 2 : 8 : 1), in a diet irradiated at 3 M rads, measured individually and compared with the unirradiated control when fed to rats, showed no irradiation effect (Table X) (13), and other work confirms this view (31).

TABLE X

Metabolizable energy value following radiation treatment
[from Read (30)]

	Calories per g. *Non-irradiated*	 *Irradiated (2·79 M rads)*
Casein	4·56 ± 0·30	4·51 ± 0·22
Lard	8·82 ± 0·31	8·87 ± 0·39
Carbohydrate (Mixture of Sucrose, starch and dextrose)	3·87 ± 0·2	3·78 ± 0·30

Similarly, the digestibilities of a number of foods, including beef, as measured by rat feeding trials, are not affected by irradiation (at a dose of 2·8 M rads). Of more direct interest are the growth results of feeding to rats 24 common dietary items, including salmon, shrimp and tuna irradiated at 3 and 6 M rads. In general, little or no difference has been found between the irradiated and control feeds and this was particularly so with the sea foods (38).

In another series of tests (18), beef, pork, tuna fish and chicken stew were fed over a 2–3 year period to dogs,

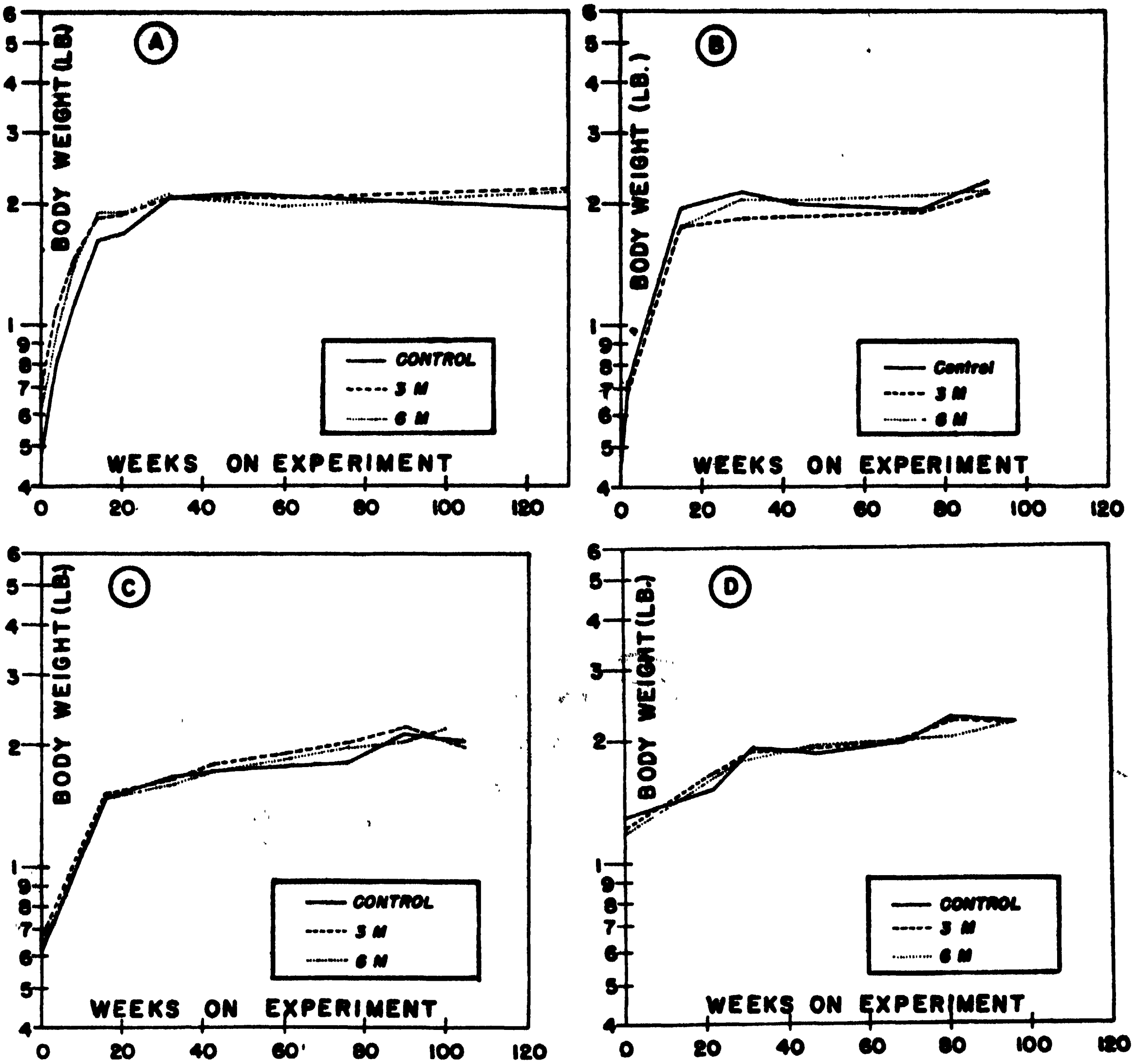

Fig. 3. Growth curves of dogs fed irradiated meats [from McCay & Rumsey (18)]. A: Beef, B: Pork, C: Chicken stew, D: Tuna fish.

during which their growth rates, health and reproductive performances were determined. The tuna and other meats were irradiated at approximately 3 and 6 M rads, and were then incorporated into the diet at levels of up to 35 per cent of the dry matter. The feeds were also vitamin supplemented. Figure 3 shows growth curves for beef and tuna which indicate no difference between controls and irradiated samples. The blood counts in both control and treated animals were very similar, and the reproductive performance (at least on pork, chicken and tuna) was unimpaired. Further results now available for cod and shrimp fed to rats and for shrimp and tuna fish fed to dogs have shown that irradiation at approximately 3 and 6 M rads has no adverse effect on the growth, reproduction, life span and disease incidence of these animals (30). Finally human feeding trials, both short and long term, involving 54 irradiated foods including meat, fish (cod and haddock, salmon, shrimp and tuna), vegetables, fruits and cereals which had already passed toxicity tests in animals, are now under way with the first results just coming to hand (25). So far as fish are concerned, these were irradiated as follows: cod, shrimp and tuna at 4 M rads and haddock, salmon, shrimp and tuna at 3 M rads.

The results of the short-term feeding of diets consisting of 100 per cent irradiated foods for periods of 15 days in a series of seven tests showed no evidence of toxic effect either by chemical examination or laboratory tests.

From all the data now available it may generally be concluded that the nutritional alterations which foods, and in particular sea foods, undergo, even with sterilizing doses are, apart from the vitamins, comparatively small. The vitamin losses, important though these are, could obviously be made good in the usual way and hence are not likely to detract from irradiation as a method of food processing.

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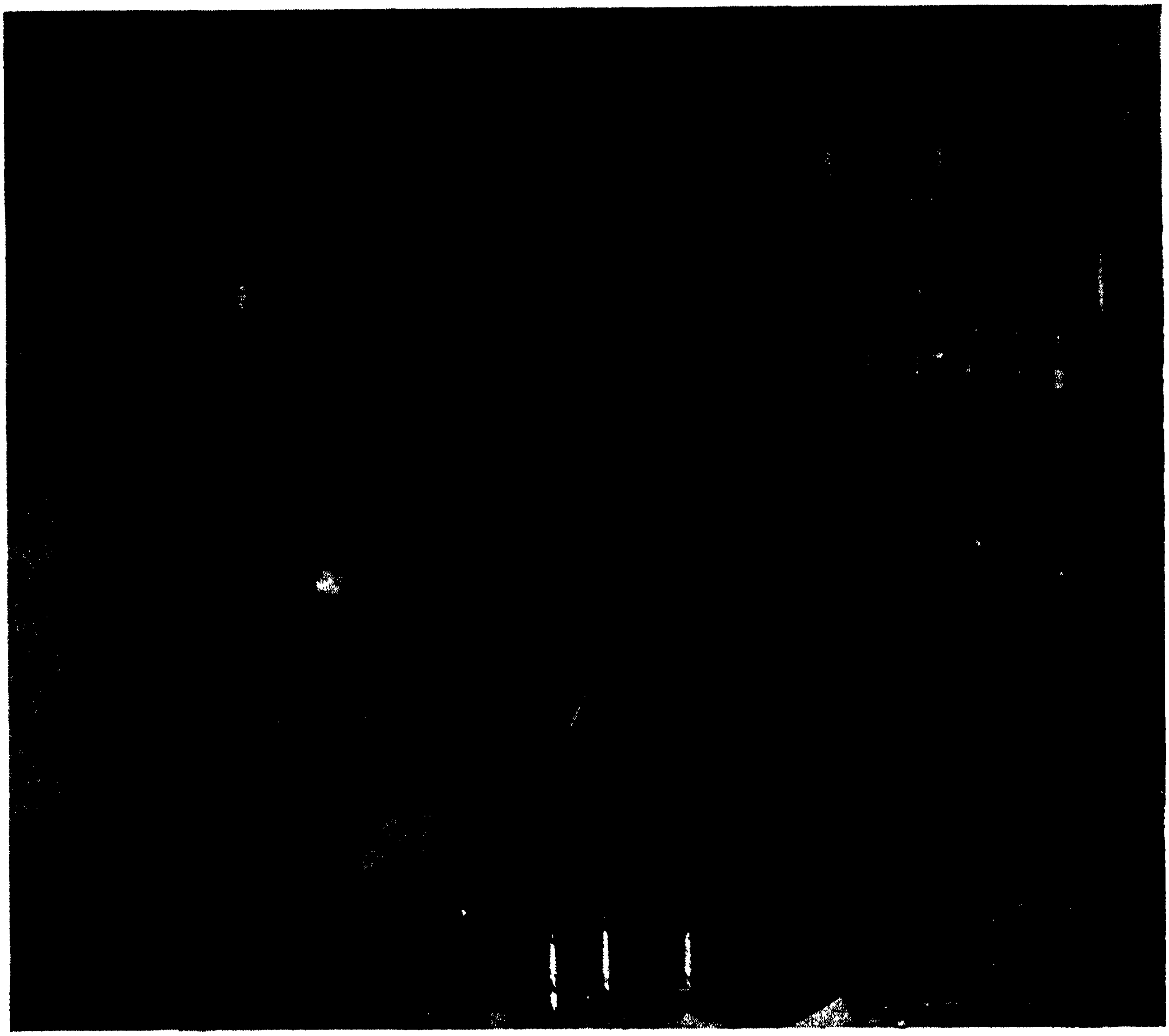


This picture has nothing to do with irradiation and the research work done on it, but it does serve to record and pay tribute to the painstakingly accurate and dedicated activity of the scientist and chemist in seeking out all pertinent facts relating to fish and fish life. As a matter of fact, it is the laboratory on board the British research vessel *Ernest Holt* which works regularly in Arctic waters seeking out the haunts of fish on which information the operator, processor and scientist can later carry on their work. Steady research on similar lines is done by other fishing countries.

THE EFFECT OF STORAGE IN REFRIGERATED SEAWATER ON THE AMINO ACIDS AND OTHER COMPONENTS OF FISH

by

EDWARD COHEN and JOHN PETERS

The fishing industry has long been in need of better ways of preserving the fresh qualities of fish. Much of the quality-loss results from improper icing both aboard the vessel and ashore. Holding the catch in refrigerated sea water is a method that shows considerable promise for maintaining freshness, both aboard ship and at the shore plant. Since this is a relatively new technique, and little is known of the effect of storage in refrigerated sea water on the various components of fish flesh, investigations were made to determine the changes in the amino acid, protein, moisture, fat, ash, sodium, potassium, and chloride content of whiting (*Merluccius bilinearis*) when stored in refrigerated sea water and in ice.

For the comparative tests reported in this paper, 500 lb. of freshly caught whiting were stored in refrigerated sea water at 30°F, and 300 lb. of whiting were stored in flake ice at 32°F. Periodically, organoleptic tests were conducted on the raw and cooked fish; and samples of the flesh were analysed for proximate composition, and amino acid, sodium, potassium, and chloride content.

The results of the organoleptic evaluation of the raw fish show little difference between those stored in refrigerated sea water and those stored in ice. The ratings of the cooked fish, however, show a consistent preference of the panel for the whiting stored in refrigerated sea water.

The results of the proximate, sodium, potassium, and chloride analyses on whiting stored in refrigerated sea water show gains in ash, sodium, and chloride; losses in fat and potassium; and no changes in protein and moisture (Table I). During iced storage there is a gain in moisture; losses in protein, fat, ash, potassium, and chloride; and no change in sodium.

The results of the amino acid analyses conducted during this test show that no significant change occurred in the majority of amino acids during storage of the fish in refrigerated sea water or in ice. On the 13th day of storage, significant amounts of methionine sulfoxide were found.

There was a simultaneous decrease in methionine in both samples.

L'EFFET DE L'ENTREPOSAGE DANS L'EAU DE MER REFRIGERES SUR LES AMINO-ACIDES ET LES AUTRES COMPOSANTS DU POISSON

L'industrie de la pêche a reclamé depuis longtemps de méthodes supérieures pour conserver au poisson ses qualités de fraîcheur Une grande part de la détérioration de la qualité résulte d'une mise en glace défectueuse à la fois en bateau et à terre. L'entreposage de la pêche dans l'eau de mer réfrigérée est une méthode extrêmement prometteuse pour en maintenir la fraîcheur à bord du navire et dans les installations à terre. Comme il s'agit d'une technique relativement nouvelle, et qu'on sait peu de choses en ce qui concerne l'effet de l'entreposage en eau de mer réfrigérée sur les divers composants de la chair de poisson, on a effectué des recherches pour préciser les modifications qui interviennent dans la teneur en amino-acides, en protéines, en eau, en graisses, en cendres, en sodium, en potassium et en chlorures du merlan (*Merluccius bilinearis*) lorsqu'on l'entrepose dans l'eau de mer réfrigérée et dans la glace.

Dans les essais comparatifs décrits dans cet article, 500 livres de merlan capturé fraîche ont été entreposées dans de l'eau de mer réfrigérée à 30°F (— 1,11°C), et 300 livres dans de la glace en écailles à 32°F (0°C). On a effectué des tests pérdiodiques sur le poisson brut et cuit, et l'on a analysé des échantillons de chair pour leur composition immédiate et pour leur teneur en amino-acides, en sodium, en potassium et en chlorure.

Les résultats de l'évaluation organoleptiques des poissons bruts montrent peu de différences entre ceux qui sont entreposés dans de l'eau de mer réfrigérée et ceux qui sont entreposés sous glace.

Les résultats de l'analyse immédiate du sodium, du potassium et des chlorures effectuée sur le merlan entreposé dans l'eau de mer réfrigérée montrent des augmentations dans les teneurs en cendres, en sodium et en chlorures, des pertes en graisses et en potassium, mais aucune variation dans les teneurs en protéines et en eau (Tableau I). Durant l'entreposage sous glace, il y a eu une augmentation de la teneur en eau, des pertes en protéines, en graisses, en cendres, en potassium et en chlorure, et aucune variation dans la teneur en sodium.

Les résultats des analyses des amino-acides effectuées durant cet essai ont montré qu'il n'y a pas de modifications significatives dans la plupart des amino-acides durant l'entreposage du poisson dans l'eau de mer ou dans la glace. On a trouvé, au bout du 13ème jour d'entreposage, des quantitiés notables de sulfoxyde de méthionine.

Il y avait une diminution simultanée de la méthionine dans les deux séries d'échantillon.

EFECTO QUE EL ALMACENAMIENTO EN AGUA DE MAR REFRIGERADA TIENE EN LOS AMINOACIDOS Y OTROS COMPONENTES DEL PESCADO

La industria pesquera necesita desde hace mucho tiempo mejores métodos para mantener la frescura del pescado. La mayor parte de la pérdida de calidad se debe a un inadecuado almacenamiento en hielo a bordo y en tierra. El almacenamiento de la captura en agua de mar refrigerada ofrece grandes posibilidades para mantener la frescura del pescado, tanto en el barco como en los establecimientos en tierra. Como ésta es una técnica relativamente nueva y se sabe muy poco del efecto que el almacenamiento en agua de mar refrigerada tiene en los diversos componentes de la carne del pescado, se realizaron investigaciones para determinar los cambios en los aminoácidos, proteínas, humedad, grasa, ceniza, sodio, potasio y cloruros que contiene la merluza americana (*Merluccius bilinearis*) cuando se almacena en agua de mar refrigerada y en hielo.

Para los ensayos comparativos mencionados en este artículo, 500 lb. de merluza americana recién pescada se almacenaron en agua de mar refrigerada a 30°F (— 1,11°C), y 300 lb. en hielo en copos a 32°F (0°C). Periódicamente se hicieron ensayos organolépticos con el pescado crudo y cocido, y muestras de la carne se analizaron para determinar la composición aproximada y el contenido de aminoácidos, sodio, potasio y cloruros.

Los resultados de la determinación organoléptica de pescado crudo arrojan poca diferencia entre el almacenado en agua de mar refrigerada y en hielo; pero la puntuación del pescado cocido demuestra que el jurado prefirió constantemente la merluza almacenada en agua de mar refrigerada.

Los resultados de los análisis aproximados de sodio, potasio y cloruro en merluza americana almacenada en agua de mar refrigerada muestran aumentos de ceniza, sodio y cloruros; pérdidas de grasa y potasio; e igualdad de proteína y humedad (Tabla I). Durante el almacenamiento en hielo aumenta la humedad; disminuyen las proteínas, grasa, ceniza, potasio y cloruros; no cambia el sodio.

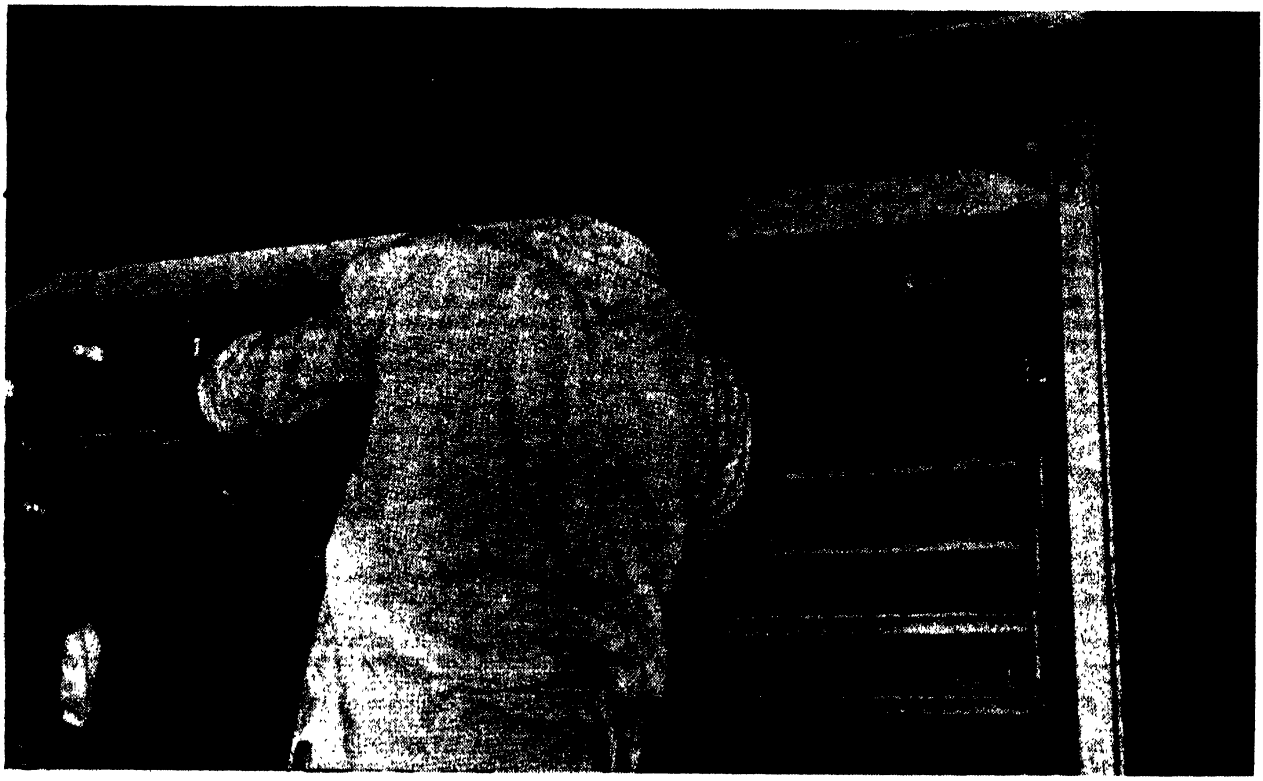
Los resultados de los análisis de aminoácidos realizados durante el ensayo demuestran que no ocurrieron cambios sensibles en la mayor parte de los aminoácidos durante el almacenamiento del pescado en agua de mar refrigerada o en hielo. En el 13° día de almacenamiento, se encontraron cantidades significativas de sulfóxido de metionina.

Hubo una disminución de metionina en ambas muestras.

TABLE I

Proximate composition, sodium, potassium, and chloride content of whiting

Storage time	*Storage medium*	*Protein*	*Moisture*	*Fat*	*Ash*	*Total of proximate components*	*Sodium*	*Potassium*	*Chloride*
Days		*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Milligrams per 100 grams*	*Milligrams per 100 grams*	*Milligrams per 100 grams*
0		16·68 ± 0·28	80·73 ± 0·13	1·35 ± 0·04	1·07 ± 0·05	99·80	80 ± 4	347 ± 26	0·149 ± 0·013
7	Refrigerated sea water	16·48 ± 0·04	80·31 ± 0·11	0·475 ± 0·03	1·47 ± 0·06	98·70	324 ± 16	280	0·484 ± 0·008
7	Ice . .	15·36 ± 0·14	83·30 ± 0·04	0·400 ± 0·08	0·844 ± 0·061	99·90	89 ± 2	215 ± 12	0·108 ± 0·022
13	Refrigerated sea water	16·51 ± 0·01	81·17 ± 0·21	0·13 ± 0·08	1·59 ± 0·02	99·40	347 ± 12	222 ± 9	0·539 ± 0·030
13	Ice . .	15·17 ± 0·07	83·51 ± 0·09	0·08 ± 0·04	0·82 ± 0·02	99·58	72 ± 2	216 ± 1	0·094 ± 0·016



Refrigeration is playing a great part in the development of all fisheries both prior to processing and after it has been accomplished. In tropical areas particularly it is valued. In this picture shore refrigeration by plate freezing of shrimps is adding to India's export wealth.

PASTEURIZATION—A METHOD OF EXTENDING STORAGE LIFE OF SHELL FISH MEATS

by

C. F. DUNKER and G. W. WHARTON

The hypothesis to be tested was that, by use of pasteurization, the normal storage life of freshly prepared shell fish meats stored at 35°F might be extended many fold. Pasteurization, as used in this investigation, is the process of using relatively mild heat treatments in the destruction of the "spoilage organisms", which normally restrict refrigerated (35°F) shelf life of shell fish meats to 10 days or two weeks. Pasteurization retains much of the original fresh flavor and appearance.

Freshly picked crabmeat, shucked oysters, shucked clams, crabcakes and lobster meats, can be stored at 35°F for 1 to 2 weeks before deteriorating organoleptically and bacteriologically. Proper pasteurization techniques can extend this storage life from 3 months to over 1 year, at 35°F storage temperature. J. V. Anzulovic and R. J. Reedy (1948) (1954) extended the storage life of crabmeat to 6 months, by bringing the internal temperature of the crabmeat to 170°F for 1 minute. G. Clifford Byrd (1951) patented a pasteurization process, using 171–210°F internal temperatures, after which crabmeat could be held at 38°F from 1 to 12 months. The Seafood Processing Laboratory extended the observations on crabmeat, and also applied pasteurization to other seafoods. The general technique used was to seal the shell fish meat hermetically in a tin can, place the can into the heating medium until the internal temperature of the product reached 170–227°F for 1 to 5 minutes, rapidly cool to 100°F, and store at 35°F. Fresh and pasteurized stored samples were tested for organoleptic and bacteriological quality. Properly handled freshly picked crabmeat, pasteurized at the Seafood Processing Laboratory from 170 to 185°F internal temperature for 1 minute, retained high quality from 8 months to over one year at 35°F. Recent tests indicate that, under carefully controlled conditions, crabmeat heated to 227°F will retain its quality well over 6 months when stored at 35°F. Tests to 12 months are still progressing.

Raw oysters, heated rapidly to 227°F and cooled, lost their fresh raw flavor. However, by heating from 140–150°F from 30 to 60 minutes, the oysters retained much of their raw characteristics and stored well for 2 months at 35°F.

Soft clams (maninose), heated to 185°F even for 5 minutes, spoiled after several weeks' storage at 35°F. However, when pasteurized to 227°F for 5 minutes and to 250°F for 4 minutes, the maninose retained high quality during storage for more than 3 months at 35°F. Tests are continuing.

Crabcake mix, pasteurized to 185°F for 5 minutes retained quality well, when stored at 35°F for 3 months. Longer storage life seems highly probable.

Lobster meat was pasteurized to 185°F for 5 minutes, and also to 227° for 5 minutes. Both sets of samples were in excellent condition after 35°F storage for 3 months. Many more months of shelf life apparently was possible. 4, 6, 9 and 12 months storage tests are scheduled.

The conclusions to be drawn from these tests are that pasteurization of shell fish meats greatly extends normal shelf life at 35°F storage (Table I). The product quality after pasteurization is much more like the fresh product than if the products were frozen or processed at high temperature over extended periods of time (commercially sterilized).

LA PASTEURISATION—METHODE POUR ETENDRE LA DUREE DE CONSERVATION DES CHAIRS DE CRUSTACES ET COQUILLAGES

On a cherché à vérifier l'hypothèse selon laquelle la pasteurisation peut étendre de plusieurs fois la durée de conservation de chairs de crustacés et coquillages fraîchement préparées et entreposées à 35°F (1,7°C). La pasteurisation, telle qu'elle a été employée dans cette étude, est le procédé, qui consiste à utiliser des traitements thermiques relativement modérés pour détruire les "organismes d'altération" qui restreignent généralement à 10 ou 15 jours la durée de conservation en étagères sous froid (35°F). La pasteurisation conserve aux produits la plus grande part de leur saveur et de leur aspect d'origine.

La chair de crabes fraîchement capturés, les huîtres et autres coquillages écailles, les miettes de crabes et la chair de homard ou de langouste peuvent être entreposés à 35°F durant 1 à 2 semaines avant de présenter une détérioration organoleptique et bactériologique. Des techniques de pasteurisation adaptées peuvent étendre cette durée de conservation de 3 mois jusqu'à 1 an à la température de 35°F. J. V. Anzulovic et R. J. Reedy (1948) (1954) ont porté la durée de conservation de la chair de crabe à 6 mois, en amenant sa température interne à 170°F (76,7°C) pendant une minute. G. Clifford Byrd (1951) a breveté un procédé de pasteurisation utilisant des températures internes de 171–210°F (77–99°C), à la suite duquel la chair de crabe pouvait être gardée à 38°F (3,3°C) durant 1 à 12 mois. La Seafood Processing Laboratory a développé les observations sur la chair de crabe, et a appliqué également la pasteurisation à d'autres aliments d'origine marine. La technique générale utilisée consistait à sceller hermétiquement la chair de crustacé ou de coquillage dans une boîte de conserve, de placer cette boîte dans un milieu de chauffage jusqu'à ce que la température interne du produit atteigne 170–227°F (76,7–108°C) durant 1 à 5 minutes, de la refroidir rapidement à 100°F (37,8°C) et de l'entreposer à 35°F. On contrôlait la qualité organoleptique et bactériologique d'échantillons frais et pasteurisés. La chair de crabe fraîchement capturé, convenablement manipulé, pasteurisé au Seafood Processing Laboratory à la température interne de 170 à 185°F (76,7 à 85°C) pendant 1 minute, conservait ses critères de haute qualité de 8 mois jusqu'à 1 an à 35°F. Des essais récents ont montré que, sous des conditions soigneusement contrôlées, la chair de crabe chauffée à 227°F conservait bien sa qualité jusqu'à 6 mois sous 35°F. Des essais à 12 mois sont encore en cours.

Les huîtres crues, chauffées rapidement à 227°F et refroidies, perdent leur saveur de fraîcheur naturelle. Cependant, chauffée entre 140 et 150°F (60 à 65,6°C) durant 30 à 60 minutes, les huîtres gardent la plupart de leurs caractères naturels et se conservent bien pendant 2 mois à 35°F.

La soft-clam (maninose) chauffée à 185°F durant 5 minutes s'altère après plusieurs semaines d'entreposage à 35°F. Cependant, pasteurisées à 227°F pendant 5 minutes, et à 250°F (121,1°C) pendant 4 minutes, la maninose conserve une haute qualité durant plus de 3 mois d'entreposage à 35°F. Les essais se poursuivent.

Le mélange de miettes de crabe ("crabcake mix"), pasteurisé à 185°F pendant 5 minutes conserve bien sa qualité durant 3 mois d'entreposage à 35°F. Il semble très probable qu'on puisse obtenir de plus longues durées de conservation.

La chair de homard a été pasteurisée à 185°F durant 5 minutes et, également, à 227°F durant 5 minutes. Les deux groupes d'échantillons étaient en conditions excellentes après un entreposage de 3 mois à 35°F. Il semble que la conservation durant de nombreux autres mois soit possible. Des essais d'entreposage de quatre, six, neuf et douze mois sont prévus.

Les conclusions qu'on peut tirer de ces essais sont que la pasteurisation des chairs de coquillages et crustacés étend largement leur durée de conservation sous froid en étagères à 35°F (Tableau I). La qualité du produit après pasteurisation est bien plus semblable à celle du produit frais qu'avec une congélation ou un traitement à haute température et de durée étendue (cas de la stérilisation industrielle).

LA PASTERIZACION: METODO PARA PROLONGAR LA DURACION EN ALMACEN DE CARNE DE MARISCOS

Se trataba de verificar la hipótesis según la cual la pasterización puede prolongar varias veces la duración de carne de mariscos recién preparada y almacenada a 35°F (1,7°C). La pasterización, tal como se ha empleado en este estudio, consiste en emplear tratamientos térmicos relativamente moderados para destruir los organismos de la deterioración que normalmente reducen a 10 ó 15 días la duración en almacén a 35°F. Con la pasterización se conserva gran parte del aspecto y sabor frescos originales.

Carne de cangrejo recién extraída, ostras y almejas desconchadas, pastelillos de carne de cangrejo y carne de bogavante pueden almacenarse a 35°F de una a dos semanas antes de que se presente la deterioración organoléptica y bacteriológica. Las técnicas de pasterización adaptadas pueden prolongar esta duración en almacén desde 3 meses a más de 1 año a la temperatura de 35°F. J. V. Anzulovic y R. J. Reedy (1948) (1954) prolongaron la duración en almacén de carne cangrejo hasta 6 meses, elevando la temperatura interna de la carne a 170°F (76,7°C) durante 1 minuto. G. Clifford Byrd (1951) patentó un procedimiento de pasterización que emplea temperaturas internas de 171°–210°F (77°–99°C), después del cual la carne de cangrejo puede mantenerse a 38°F (3,3°C) de 1 a 12 meses. El Seafood Processing Laboratory amplió las observaciones sobre la carne de cangrejo y aplicó igualmente la pasterización a otros alimentos de origen marino. La técnica general empleada consistía en cerrar herméticamente la carne del marisco en una lata, poner ésta en un medio de calentamiento hasta que la temperatura interna del producto alcanzaba de 170° a 227°F (76,7° a 108°C) durante 1 a 5 minutos, enfriarla ràpidamente a 100°F (37,8°C) y almacenarla a 35°F. Se determinó la calidad organoléptica y bacteriológica de muestras frescas y almacenadas. La carne de cangrejo recién extraída, convenientemente manipulada, pasterizada en el Seafood Processing Laboratory a la temperatura interna de 170° a 185°F (76,7 a 85°C) durante 1 minuto, conservaba su excelente calidad desde 8 meses hasta más de 1 año a 35°F. Ensayos recientes han demostrado que, en condiciones cuidadosamente reguladas, la carne de cangrejo calentada a 227°F retiene su calidad durante bastante más de 6 meses cuando se almacena a 35°F. Se hacen todavía ensayos de 12 meses de duración.

Las ostras crudas, calentadas rápidamente a 227°F y enfriadas, perdieron su sabor fresco natural; pero calentándolas de 140° a 150°F (60° a 75,7°C) de 30 a 60 minutos conservaban gran parte de su sabor característico natural y se conservaban bien durante 2 meses a 35°F.

Las almejas de concha blanda (maninose), calentadas a 185°F durante 5 minutos, se echaban a perder después de varias semanas de almacenamiento a 35°F; pero cuando se pasterizaban a 227°F durante 5 minutos, y a 250°F (121,1°C) durante 4 minutos, conservaban una alta calidad durante más de 3 meses de almacenamiento a 35°F. Continúan los ensayos.

Las mezclas para preparar pastelillos de cangrejo pasterizadas a 185°F durante 5 minutos conservan bien la calidad cuando se almacenan a 35°F durante 3 meses. Parece ser muy probable que se logre una mayor duración en almacén.

La carne de bogavante se pasterizó a 185°F durante 5 minutos, y a 227°F por el mismo tiempo. Ambos grupos de muestras estaban en excellentes condiciones tras un almacenamiento de 3 meses a 35°F. Parece ser posible la conservación durante muchos más meses. Se preparan ensayos de 4, 6, 9 y 12 meses de almacenamiento.

Las conclusiones que se pueden sacar de estos ensayos son que la pasterización de la carne de mariscos prolonga mucho su duración en almacén a 35°F (Tabla I). La calidad del producto después del a pasterización se parece mucho más a la del fresco que si se hubiera congelado o tratado a temperaturas elevadas o durante mucho tiempo (esterilización industrial).

TABLE I

of effect of pasteurization of shell fish meats on extension of storage life at 35°F (1·7°C)

Type of product	*Pasteurization (internal temp.)*	*Storage life unpasteurized*	*Storage life pasteurized*
	°C	*Months*	*Months*
Crabmeat	77–85	¼–½	6–24
Clam meat	108	½	4
Oyster meat	60–66	½	2
Lobster meat	108	½	4
Crabcake mix	85	½	4

ON TOUGHNESS OF BOILED FISH MEAT

by

TOYO-O TAKAHASHI

Histological and physical properties of fish meat boiled in water and in solutions of certain chemicals were studied in order to determine the causes of different degrees of toughness developed in different fish meat on boiling. Attempts were also made to soften boiled squid meat which had gone tough. No significant differences were found, either before or after boiling, in inter-fibrillar spaces in the meat of fish which developed different degrees of toughness on boiling. Non-myosin content bore direct relation to the degree of toughness, while the opposite was true of the water content. On boiling, the non-myosin coagulated and filled in the inter-fibrillar spaces, thereby increasing the cohesion of the muscle fibers. Treatment with pyrophosphate solution prior to boiling rendered the meat less tough, but reduced the inter-fibrillar spaces. Stress in squid muscle, when heated in water, rose abruptly at 50°C and continued to rise with increasing temperature; the process could be reversed a few times. The stress fell when the muscle was heated or cooled a few times in 0·1 M β-napthalene sulphonate or 10 M urea solution. Compared with boiling in water, the rate of increase in stress in the muscle was the same when boiled in β-naphthalene sulphonate, but less steep when boiled in urea. When boiled squid meat was subsequently boiled in urea (10 M) or alkaline (pH 10) solution at 100°C for an hour, the breaking strength (F) along the muscle fibers decreased while the extension (E) increased, both considerably. When treated the same way with acids, F was entirely lost; upon boiling in 0·01 M lactic acid, E remained almost constant, while F decreased. Similar treatment in 0·001 M hydrochloric acid increased F, but decreased E to some extent. It is suggested that squid meat possesses a three-dimensional network, as does rubber, and that the physiochemical characters of the joints of the chains are different from that of the linkage held by the chains, and that these chains and linkages are affected differently by different chemical reagents.

AU SUJET DE LA DURETE DE LA CHAIR BOUILLIE DE POISSON

On a étudié les propriétés histologiques et physiques de la chair de poisson bouillie dans l'eau et dans certaines solutions chimiques, afin de préciser les causes des divers degrés de durcissement qui se développent dans diverses chairs de poisson lorsqu'on les fait bouillir. On a également tenté de rendre plus tendre du calmar qui, bouilli, était devenu coriace. On n'a pas trouvé de différences significatives avant et après ébullition dans les espaces inter-fibrillaires de la chair de poisson, qui présentait un durcissement de degré divers lorsqu'on l'avait fait bouillir. La teneur de la fraction autre que la myosine est en relation directe, et la teneur en eau en relation inverse, avec la degré de durcissement. A l'ébullition, la fraction autre que la myosine se coagule et remplit les espaces inter-fibrillaires, entraînant une cohésion plus forte des fibres musculaires. Un traitement avec du pyrophosphate en solution avant ébullition a rendu le muscle moins coriace, mais a réduit les espaces inter-fibrillaires. La contraction dans le muscle de calmar chauffé dans de l'eau augmente brutalement, lorsqu'on arrive à 50°C et continue à augmenter avec l'accroissement de température; le processus peut être renversé plusieurs fois durant quelques minutes. La contraction diminue quand le muscle a été alternativement chauffé et refroidi à quelques reprises dans du sulfonate de β-naphtalène 0,1 M ou de le solution d'urée 10 M. Pour l'ébullition dans le sulfonate de β-naphtalène, le taux d'accroissement de la contraction du muscle était identique pour l'ébullition dans l'eau; mais, pour l'ébullition dans l'urée, ce taux était moins fort. Quand la chair de calmar bouillie était ensuite soumise à une ébullition dans l'urée (10 M) ou dans une solution alcaline (pH 10) à 100°C durant 1 heure, la résistance à la rupture (F) des fibres musculaires décroissait, tandis qu'augmentait leur coefficient d'extension (E), tous deux d'une façon considérable. Pour des fibres traitées de la même manière dans l'acide, F devenait nul; et pour une ébullition dans une solution lactique à 0,01 M, E restait approximativement constant tandis que F décroissait. Un traitement similaire dans de l'acide chlorhydrique très dilué à 0,001 M augmentait F, mais diminuait E dans une certaine mesure.

On peut croire que la chair de calmar présente une texture tri-dimensionnelle comme le caoutchouc, et que les caractères physico-chimiques des liaisons entre chaînes sont différents de ceux des liaisons internes des chaînes, et que ces chaînes et ces liaisons sont différemment affectées par les divers agents chimiques.

SOBRE LA DUREZA DE LA CARNE DE PESCADO HERVIDA

Se estudiaron las propiedades histológicas y físicas de carne de pescado hervida en agua y en soluciones de diversas substancias químicas, para determinar las causas de los diferentes grados de dureza que se presenta en la de pescados distintos al hervirlos. También se trató de ablandar carne de calamar hervida que se había endurecido. No se observaron diferencias de importancia antes o después de hervir en los espacios interfibrilares del pescado que se endureció en distintos grados al hervirlo. La ausencia de miosina estaba en relación directa con el grado de dureza, en tanto que ocurría lo contrario con el contenido de agua. El tratamiento con una solución de pirofosfato antes de hervir hacía la carne menos dura, pero reducía los espacios interfibrilares. La tensión en el tejido muscular del calamar calentado en agua aumentó rápidamente al llegar a 50°C y siguió aumentando con el incremento de la temperatura. El proceso podía alterarse, algunes vezes durante unos pocos minutos. La tensión disminuía cuando la carne de calamar se calentaba o enfriaba varias veces en una solución de β-naftaleno sulfonato 0,1 M o de urea 10 M. En comparación con la ebullición en agua, la velocidad de aumento de la tensión era igual cuando se hervía en β-naftaleno sulfonato, pero menos intensa cuando se hervía en urea. Cuando la carne de calamar hervida se hervía de nuevo en urea (10 M) o solución alcalina de pH 10 a 100°C durante 1 hora, la resistencia a la rotura (F) a lo largo de las fibras musculares decrecía, en tanto que la extension (E) aumentaba, ambas considerablemente. Cuando se trataba de la misma manera con ácido, F se perdía por completo. Al hervir en solución láctica 0,10 M, E se mantenía casi constante en tanto que F disminuía. El tratamiento análogo en ácido clorídrico 0,001 M aumentaba F, pero reducía en cierto grado E. Se sugiere que la carne de calamar posee una reticulación de tres dimensiones como el caucho, y que las características fisicoquímicas de los puntos de unión de las cadenas son diferentes de los eslabones que formen y que tanto en las cadenas como los eslabones influyen de manera distinta los reactivos químicos diferentes.

TABLE I

Water contents and contents of non-myosin fraction in boiled meat and in fresh meat of various fishes, percentage

Species	*Water-contents in boiled[1] meat*	*Contents in fresh meat*		*Behaviour of boiled meat*	*Contents of non-myosin fraction in fresh meat*
		Water	*Fat*		
Thunnus orientalis (Bluefin tuna)	65·0–68·0	74·7–76·0			7·01, 10·11
Katsuwonus vagans (Skipjack)	67·1	71·8	0·05	Tough	7·38, 8·70
Auxis tapeinosoma (Frigate mackerel)	70·1	72·9	0·4		11·25
Kareius bicoloratus (A kind of flat fish)					2·37
Limanda aspera (A kind of flat fish)	81·4, 82·1	83·3, 83·1	0·3	Soft	3·25, 3·62
Theragra chalcogramma (Alaskan pollack)					2·32, 2·62
Trachipterus ishikawai (King of the herrings)	85·6	90·7	0·1		2·38

[1] At 100°C, for 30 minutes.

While the scientist is rightly concerned about the nutritive value and palatability of boiled fish, these housewives in Rio de Janeiro in Brazil are more concerned to have some fish to boil. They have a nice selection on a street market stall from which to choose.

FISH SAUSAGE IN JAPAN

by

MINORU OKADA

The fish sausage industry has grown rapidly in Japan during the last 10 years. The estimated production in 1960 was 72,000 tons. In addition to its excellent eating qualities, fish sausage has the special advantage in that it keeps well for over one month even at 30°C. In the present paper the author gives an outline of the processing techniques and results of his experiments on the requirements for the manufacture of high quality fish sausage.

Meat of such fish as tuna, marlin, shark, and whale, mixed with starch, salt (the main additive), spices, seasonings, liquid smoke, fat, polyphosphates and chemical preservatives, is finely ground in power mortars. The resulting emulsion is encased in rubber hydrochloride or polyvinylidene chloride film, and cooked in water at 90°–95°C for 50–60 minutes. Good quality fish sausage contains from 10–18 per cent protein, 3–10 per cent fat, 60–70 per cent water, the remaining portion being comprised of starch and other additives.

The quality of fish sausage prepared from meat of different fish varies greatly. Marlin meat gels the best. The jelly-forming capacity of fish flesh is generally the same for all fish immediately after death; during storage this capacity falls at varying rates for different species of fish. Polyphosphates added *pre-rigor* slow down the rate of fall in the jelly-forming capacity during storage. Best elasticity results when the muscle protein is well dissolved. The salt concentration of about 3 per cent and pH of 6·5–7 produce the best elastic jelly. Polyphosphates enhance elasticity by facilitating dissolution of the myosin.

The jelly strength usually increases with the rise of cooking temperature; with some meat the highest cohesiveness is obtained by cooking below 50°C. Cooking by two stages, namely, first at 45°–50°C, and then at above 85°C, is more effective for good elasticity and preservation.

Considerable bacteriological research on the keeping quality of fish sausage has been, and is, currently underway at the author's laboratory.

LA SAUCISSE DE POISSON AU JAPON

L'industrie de la saucisse de poisson s'est développée rapidement au Japon au cours des dix dernières années. La production estimée en 1960 a été de 72,000 tonnes. En plus de ses excellentes qualités à la consommation, la saucisse de poisson présente l'avantage particulier de pouvoir être conservée correctement durant un mois, même à 30°C. Dans le présent article, l'auteur donne un aperçu sur les méthodes de préparation et sur les résultats de ses propres expériences en ce qui concerne les exigences de fabrication pour obtenir une saucisse de poisson de haute qualité.

La chair des poissons tels que le thon, le voilier, le requin et la baleine, mélangée avec de la fécule, du sel (l'additif principal), des épices, des assaisonnements, de la "fumée liquide", des graisses, des polyphosphates et des agents chimiques de préservation, est finement broyée dans des mortiers puissants. L'émulsion résultante est enfermée sous pellicule de caoutchouc chloré ou de chlorure de polyvinyle, et cuit dans de l'eau à 90°–95°C durant 50 à 60 minutes. La saucisse de poisson de bonne qualité contient de 10 à 18% de protéines, 3 à 10% de graisses, 60 à 70% d'eau, le solde comprenant la fécule et les autres additifs.

La qualité de la saucisse de poisson varie beaucoup selon la chair des divers poissons employés. La chair de voilier est celle qui gélifie le mieux. Le pouvoir de gélification de la chair de poisson est généralement le même pour tous les poissons immédiatement après leur mort; elle diminue durant l'entreposage d'une façon différente selon les espèces. Les polyphosphates ajoutés avant la *rigor mortis* contrecarrent cette diminution du pouvoir de gélification au cours de l'entreposage. On obtient la meilleure élasticité lorsque les protéines musculaires sont bien dissoutes. Une concentration en sel de 3% environ et un pH de 6,5 à 7 donnent la gelée la plus élastique. Les polyphosphates augmentent l'élasticité en facilitant la dissolution de la myosine.

La cohésion de la gelée augmente d'habitude avec l'accroissement de la température de cuisson, mais avec quelques chairs de poisson la plus haute cohésion s'obtient par une cuisson à une température inférieure à 50°C. Une cuisson à deux étages de température, soit d'abord à 45–50°C et ensuite au-dessus de 85°C, est plus efficace pour fournir une bonne élasticité et une bonne conservation.

Une importante série de recherches bactériologiques concernant les qualitiés de conservation de la saucisse de poisson ont été effectuées et se poursuivent normalement au laboratoire de l'auteur.

LOS EMBUTIDOS DE PESCADO EN EL JAPON

La industria de los embutidos de pescado se ha desarrollado rápidamente en el Japón en los últimos 10 años. La producción de 1960 se estimó en 72,000 tons. Además de sus excelentes calidades de consumo, el embutido de pescado tiene la ventaja especial de que se conserva bien durante un mes, incluso a 30°C. En este artículo el autor bosqueja los métodos de preparación y los resultados de sus investigaciones sobre las necesidades indispensables para producir embutidos de pescado de gran calidad.

Carne de peces como atún, pez vela, y tiburón y de ballena se mezclan con almidón, sal (el principal aditivo), especias, condimentos, humo líquido, grasa, polifosfatos y agentes conservadores químicos, y se pica finamente en morteros mecánicos. La emulsión resultante se embute en caucho clorado o cloruro de polivinilideno, y se cuece en agua a 90°–95°C de 50 a 60 minutos. El embutido de pescado de buena calidad contiene de 10 a 18% de proteína; 3 a 10% de grasa; 60 a 70% de agua, y el resto lo forman el almidón y los otros aditivos.

La calidad de los embutidos de pescado varía mucho según la carne de las especies empleadas. La del pez vela es la que mejor gelifica. La capacidad de gelificar de la carne del pescado es generalmente igual para todos inmediatamente después de la muerte, pero durante el almacenamiento disminuye de manera distinta según las especies. Los polifosfatos adicionados antes de la *rigor mortis* reducen esta disminución de la capacidad de gelificación durante el almacenamiento. Se logra la mayor elasticidad cuando la proteína del tejido muscular está bien disuelta. Una concentración de sal de alrededor de 3% y un pH de 6,5 a 7 dan la jalea más elástica. Los polifosfatos aumentan la elasticidad al facilitar la disolución de la miosina.

Generalmente la cohesión de la jalea aumenta con el incremento de la temperatura de cocción; con algunas carnes la mayor cohesión se obtiene cociendo a menos de 50°C. Una cocción en dos partes, por ejemplo, primero a 45°–50°C y después a más de 85°C, es más eficaz para lograr una buena estabilidad y conservación.

En el laboratorio del autor se ha realizado y se sigue realizando una importante serie de investigaciones bacteriológicas sobre el mantenimiento de la calidad de los embutidos de pescado.

TABLE I

Chemical composition of fish sausage

(Figures in per cent)

Values	*Moisture*	*Protein*	*Fat*	*Starch*	*Sugar*	*Ash*[1]
Maximum	71·5	18·2	3·2	10·4	2·4	3·4
Mean	68·5	15·2	5·9	6·3	1·6	2·6
Minimum	61·3	10·7	2·7	3·0	0·5	2·0

[1] Ash consists mainly of sodium chloride.

While Japan has developed a considerable output of fish sausage, her lead is being followed by other countries. Canada, in particular, has shown initiative in evolving new products through processing. Interest attaches to a product closely similar to the Japanese fish sausage, namely fish weiners. The basic procedure as described in *Canadian Trade News*, May 1962, is to take chunks of frozen fillets of varied species of fish, mince them to a pulp in a grinder and blend according to a precise formula with fat, spices, water and a cereal binder. The homogenized product is then stuffed into animal or cellulose casings and tied off in links. Chains of these links are smoked according to a pre-determined schedule following which they are cooked in water and chilled. Illustration shows the Canadian operator with a batch of weiners loosely hung on a steel frame ready for insertion into the smoking tunnel.

EFFECT OF SEVERAL PROCESSING VARIABLES ON THE PROTEIN CONTENT AND QUALITY OF FISH FLOUR

by

C. H. KURTZMAN, D. G. SNYDER, L. E. OUSTERHOUT, F. T. PISKUR and P. F. BRAUCHER

Chemical analyses and rat and chick bioassays were conducted to determine whether it was the varieties in methods of processing, or between different portions of the fish (whole fish, fillet, or gurry) utilized in processing, which cause differences in the content or quality of the protein of fish flour. A single catch of ocean perch was processed or separated into whole fish, fish fillets, and fillet wastes. Samples of each of these were processed into flours by two different methods.

Considerable differences in proximate composition were obtained when the various samples were analysed by standard procedures. Protein content ranged from 72·9 to 94·6 per cent; fat content ranged from 0·0 to 0·8 per cent; ash content ranged from 0·3 to 21·8 per cent; and moisture content ranged from 0·2 to 5·7 per cent. The differences can be related both to methods of processing and to part of the fish utilized in processing.

In the rat bioassay, mean gains in weight were obtained and protein efficiency ratios were calculated for groups of male and female rats, and estimated gains of the rats of each group were computed from a multiple regression analysis. Mean apparent digestibilities of the calculated protein consumed by individual rats were determined. Results indicate that there are differences in the protein quality of various fish flours, due primarily to differences in utilization rather than to apparent digestibility of the protein.

In the chick bioassay, mean gains in weight were obtained and protein efficiency ratios were calculated for groups of male chicks. Results here also indicate differences in the protein quality of the various fish flours.

The relative ranking of the fish flours tested in terms of protein quality is virtually reversed when chicks rather than rats are used as the test animals. However, with both animals the method of processing utilized in preparing the fish flours appears to be a primary contributing factor, while the portion of the fish used appears to be a secondary contributing factor in explaining the differences in protein quality observed. In spite of differences in protein quality, all the flours tested can be considered to be of good or excellent quality when compared to controls of casein for rats and soybean oil meal for chicks.

Research was conducted: Technological Laboratory, College Park, Maryland, Bureau Commercial Fisheries, U.S. Dept. of the Interior; College of Home Economics, University of Maryland.

EFFETS DE PLUSIEURS VARIABLES DE TRAITEMENT SUR LA TENEUR EN PROTEINES ET LA QUALITE DE LA FARINE ALIMENTAIRE DE POISSON

Des analyses chimiques et des essais biologiques sur rat et sur poulet ont été effectués pour savoir si c'était les variables de la méthode de traitement, ou celles des portions du poisson utilisées dans le traitement (poisson entier, filets ou déchets), qui amenaient des différences en quantité dans les protéines de la farine alimentaire de poisson. Des chèvres provenant d'une seule pêche ont été traitées ou séparées en poissons entiers, filets de poisson et déchets de filetage. Des échantillons de chaque catégorie ont été transformés en farine alimentaire par deux méthodes différentes.

On a trouvé des divergences considérables dans la composition immédiate en analysant les divers échantillons suivant des modes opératoires normalisés. La teneur en protéines variait de 72,9 à 94,6%; celle en graisses de 0,0 à 0,8%; celle en cendres de 0,3 à 21,8% et celle en eau de 0,2 à 5,7%. Ces différences peuvent être attribuées à la fois à la méthode de traitement et à la partie du poisson soumise au traitement.

Dans les essais biologiques sur rat, on a mesuré les gains moyens en poids et calculé les rapports d'efficacité protéique sur des groupes de rats mâles et femelles; et on a calculé les gains estimés des rats de chaque groupe par une analyse de régression multiple. On a déterminé les digestibilités moyennes apparentes des protéines calculées qu'a consommé individuellement chaque rat. Les résultats montrent qu'il y a des différences dans la qualité protéique des diverses farines de poissons, et que ces différences sont d'abord provoquées par des différences dans l'utilisation des protéines plutôt que par leur digestibilité apparente.

Dans les essais biologiques sur poulet, on a mesuré les gains moyens en poids et calculé les rapports d'efficacité protéique sur des groupes de poulets mâles. Les résultats montrent également ici des différences dans la qualité protéique des diverses farines alimentaires de poisson.

L'ordre relatif des farines alimentaires de poisson, éprouvé sur la base de la qualité protéique, est virtuellement renversé quand on utilise comme sujets d'épreuve des poulets au lieu de rats. Cependant, avec ces deux espèces d'animaux, la méthode de traitement utilisée pour préparer les farines alimentaires de poisson paraît être le facteur principal, et la portion de poisson utilisée le facteur secondaire, pour expliquer les différences observées dans la qualité protéique.

En dépit de différences dans la qualité protéique, toutes les farines alimentaires essayées peuvent être considérées de bonne ou d'excellente qualité par comparaison avec des rations-témoins de caséine pour les rats et de farine de tourteau de soja pour les poulets.

EFECTO DE DIVERSAS VARIABLES DE LA ELABORACION EN EL CONTENIDO DE PROTEINAS Y CALIDAD DE LA HARINA DE PESCADO

Se realizaron análisis químicos y ensayos biológicos con ratas y pollos para determinar si las variables de los procedimientos de elaboración o de las partes del pescado (pescado entero, filetes o desechos) empleados en el tratamiento producen diferencia en el contenido o calidad de la proteína de la harina de pescado. La gallineta procedente de un solo lance se elaboró o se separó en pescado entero, filetes o desechos de filetes. Con muestras de cada clase se prepararon harinas por dos métodos diferentes.

Se encontraron diferencias considerables en la composición aproximada cuando las diversas muestras se analizaron según los procedimientos normales. El contenido de proteína vario de 72,9 a 94,6%; el de grasa, de 0,0 a 0,8%; el de ceniza, de 0,3 a 21,8; y el de humedad, de 0,2 a 5,7%. Estas diferencias pueden atribuirse tanto al método de tratamiento como a la parte del pescado empleada en la elaboración.

En los ensayos biológicos con ratas, se midieron los promedios de los aumentos de peso y se calcularon las relaciones de eficacia de la proteína para grupos de ratas macho y hembra, y los aumentos estimados para las ratas de cada grupo se determinaron por un análisis de regresión múltiple. Se determinaron las digestibilidades aparentes medias de la proteína calculada como consumida individualmente por las

ratas. Los resultados indican que existen diferencias en la calidad de la proteína de varias harinas de pescado, debidas principalmente a diferencias en utilización de las proteínas más bien que a su digestibilidad aparente.

En los ensayos biológicos con pollos se midieron los aumentos medios de peso y se calcularon las relaciones de eficacia de la proteína para grupos de pollos macho. Los resultados muestran igualmente que existen diferencias en la calidad de la proteína de las diversas harinas de pescado.

El orden relativo de las harinas de pescado ensayadas, basado en la calidad de la proteína, se trastoca virtualmente cuando se usan pollos, en vez de ratas, como animales de ensayo. Sin embargo, con ambos animales el procedimiento de elaboración empleado en la preparación de las harinas de pescado parece ser el factor principal, en tanto que la parte del pescado empleada parece ser un factor secundario para explicar las diferencias observadas en la calidad de la proteína. A pesar de las diferencias de la calidad de la proteína, todas las harinas ensayadas pueden considerarse como de calidad buena o excelente cuando se comparan con testigos de caseína para ratas y de harina de torta de soja para pollos.

View of one of the laboratories maintained in S. Africa in connection with the development of fish meal and fish flour on which a great deal of valuable pioneering and practical research work in relation both to human and stock nutrition has been done. This is essentially a field where the chemist plays a pre-eminently important rôle seconded by the support necessarily given by the production engineer in designing methods which will perfect techniques for utilizing fish resources. —*S. African Govt. Photo.*

NUTRITIONAL AND CHEMICAL CHANGES IN THE LIPID FRACTION OF STORED ANTI-OXIDANT-TREATED AND UNTREATED HERRING MEALS

by

B. E. MARCH, J. BIELY, F. CLAGGETT and H. L. A. TARR

For over a decade collaborative research under contracts has been conducted between the three senior authors, and has resulted in publication of well over 20 papers concerning such varied topics as effect of heat on availability of essential amino acids and nutritional value of herring meal protein, vitamin and "UGF" studies, and an investigation of gel formation in solubles, and other problems. Since these researches have continually shown that herring meal, as normally produced, is a comparatively stable material in its ability to provide high-quality protein, and that in this respect it differs considerably from meals produced from some sardine species and from menhaden, our current investigations are largely concerned with the lipid fraction of stored herring meals (extracted with chloroform-methanol 2 : 1).

Strangely enough, little appears to be known regarding the nutritional availability of the lipid fraction of "fatty" fish meals. This fraction often accounts for over 10 per cent of the weight of herring meals, and is of course very unstable. Completed investigations (March *et al.*, *J. Amer. Oil Chem. Soc.* **38**, 80, 1961, and submitted for publication) have revealed the following interesting results concerning the nutritive value of the lipid fraction:

(1) Storage of herring meals at −20°C results in a more rapid decrease in ethyl ether extractable lipid and in iodine values than does storage at 25·5°C. When fed at a 10 per cent level in a basal ration containing wheat, corn, soybean meal and fish meal, the extracted lipid fraction from − 20°C stored meal was less efficiently utilized than that from 25·5°C stored meal (storage up to 11 months).

(2) Addition of finely divided BHT antioxidant (0·15 per cent) resulted in herring meal from which the lipid fraction was more readily extracted after long storage, and which had higher iodine values. However, though *in vitro* pepsin digestibility was somewhat higher with the antioxidant-treated meals, this treatment did not improve the value of the meals as suppliers of nutritionally available protein for chick growth.

(3) At a 10 per cent dietary level the lipid fraction of herring meals stored for 11 months did not have adverse effects on growth, provided the ration was well fortified with vitamins. The lipid extracts in almost all instances improved efficiency of feed utilization, but not so well as did ordinary herring oil. The extracts from antioxidant-treated meals were utilized a little more efficiently than those from untreated meals. Roughly 10 per cent of unextractable lipid remained in stored untreated meals, and data indicate this is not utilized nutritionally.

A detailed report is available as: Circular No. 25, Technological Station, Fisheries Research Board of Canada, Vancouver 8, B.C.

CHANGEMENTS D'ORDRE NUTRITIF ET CHIMIQUE DE LA FRACTION LIPIDIQUE DANS LES FARINES BRUTES DE HARENG TRAITEES ET NON TRAITEES AUX ANTIOXYDANTS

Des recherches collaboratives ont été conduites sous contrats depuis plus d'une décade par les trois principaux auteurs, et elles se sont traduites par la publication de plus de 20 articles aux sujets aussi variés que les effets de la chaleur sur la disponibilité en amino-acides essentiels et la valeur nutritive des protéines de farine brute de poisson, que les vitamines et les f.c.n.i. (facteurs de croissance non identifiés), que la formation de gel dans les solubilisés, et autres problèmes. Etant donné que ces recherches ont constamment montré que la farine brute de hareng de fabrication normale est un produit relativement fidèle, quant à sa capacité de fournir des protéines de haute qualité, et qu'il diffère quelque peu à cet égard des farines brutes obtenues depuis certaines espèces de sardines ou depuis le menhaden, nos études courantes ont porté pour la plupart sur la fraction lipidique des farines brutes de hareng entreposées (fraction extraite au chloroforme méthanolé à 2:1).

Il semble assez étrange qu'on ne semble savoir que si peu de chose sur l'importance alimentaire de la fraction lipidique des farines brutes "grasses" de poisson. Cette fraction intervient souvent pour plus de 10% dans le poids des farines brutes de hareng, et elle est (bien entendu) très instable. Des recherches complètes (March *et al.*, *J. Amer. Oil Chem. Soc.* **38**, 80, 1961 et en cours de publication) ont apporté les résultats interessants suivants au sujet de la valeur nutritive de la fraction lipidique:

(1) L'entreposage des farines brutes de hareng à −20°C se traduit par une diminution plus rapide de la teneur en lipides extractibles et de l'indice d'iode qu'un entreposage à 25,5°C. Fournie au taux de 10% dans une ration alimentaire de base contenant du blé, du maïs, de la farine de soja et de la farine brute de poisson, la fraction lipidique extraite d'une farine entreposée à −20°C se montrait moins efficace que celle d'une farine entreposée à 25,5°C (entreposage atteignant 11 mois).

(2) L'addition de l'antioxydant HTB finement divisé (à 0,15%) se traduisait par une farine brute de hareng dans laquelle la fraction lipidique s'extrayait plus facilement après un long entreposage et qui présentait des indices d'iode plus haut. Cependant, quoique la digestibilité des pepsines *in vitro* fût quelque peu plus haute dans les farines traitées à l'antioxydant, ce traitement n'améliorait pas leur valeur pour fournir des protéines nutritionnellement utiles à la croissance des poulets.

(3) Au taux alimentaire de 10%, la fraction lipidique des farines brutes de hareng entreposées pendant 11 mois ne présentait pas d'effets contraires sur la croissance, pourvu que la ration fût bien renforcée en vitamines. Les extraits lipidiques dans presque tous les cas améliorait l'efficacité de l'utilisation de la nourriture, mais moins bien que l'huile commune de hareng. Les extraits de farines brutes traitées aux antioxydants étaient utilisées d'une façon légèrement moins efficace que ceux des farines non traitées. Il restait dans les farines non traitées entreposées 10%, en gros, de lipides non extractibles, et les données indiquent qu'ils ne sont pas utilisables sur le plan nutritif.

Un rapport détaillé est publié comme: Circular No. 25, Technological Station, Fisheries Research Board of Canada, Vancouver 8, B.C.

CAMBIOS NUTRITIVOS Y QUIMICOS EN LA FRACCION LIPIDICA EN HARINAS DE ARENQUE TRATADOS CON ANTIOXIDANTE Y SIN TRATAR

Desde hace mas de 10 años los tres autores principales han realizado bajo contrato y en colaboración investigaciones que han dado por resultado la publicación de mas de 20 informes relativos a temas tan diversos como efecto del calor en la disponibilidad de amino acidos esenciales y el valor nutritivo de la proteina de harina de arenque, vitaminas y factores de crecimiento no identificados, una investigación de la formación de geles en solubles, y varios otros problemas. Como estas investigaciones han demostrado constantemente que la harina de arenque que se fabrica normalmente tiene una capacidad relativamente estable de suministrar proteina de alta calidad, y que en este particular es algo diferente de las harinas fabricadas con algunas especies de sardinas y menhaden, nuestros investigaciones actuales se circunscriben principalmente a la fracción lipídica de harinas de arenque almacenadas (extractados cloroformo-metanol 2 : 1).

Por extraño que parezca, se sabe muy poco de la disponibilidad para la nutrición de la fracción lipídica de las harinas de pescado graso. Con frecuencia a esta fracción corresponde mas del 10% del peso de las harinas de arenque y es muy inestable. Investigaciones completadas ya (March *et al., J. Amer. Oil Chem. Soc.* 38, 80, 1961 y presentadas para su publicación) han revelado los interesantes resultados concernientes al valor nutritivo de la fracción lipídica que siguen:

(1) Almacenar las harinas de arenque a −20°C produce una disminución mas rápida en los lípidos extractables con eter etílico y en los índices de yodo que el almacenamiento a 20°C. Cuando la harina almacenada a −20°C se adiciona en proporción de un 10% a una ración básica que contenga trigo, maiz, harina de soja y harina de pescado, la fracción lipídica extractada no se aprovecha tan eficazmente como la de la harina almacenada a 25,5°C (en almacen hasta 11 meses).

(2) Mediante la adición (0,15%) del antioxidante HTB finamente dividido se obtuvo una harina de arenque de la que la fracción lipídica se extractaba mas fácilmente tras prolongada almacenamiento y tenía índices de yodo mas altas. Sin embargo, aunque la digestibilidad de la pepsina *in vitro* era algo mayor en las harinas tratadas con el antioxidante, el tratamiento no mejoraba el valor de las harinas como fuentes de proteina disponible nutritivamente para el crecimiento de pollos.

(3) En la proporción de un 10% de la alimentación, la fracción lipídica de harinas de arenque almacenadas 11 meses no tenía efectos perjudiciales en el crecimiento, a reserva de que la ración se fortificase bien con vitaminas. En casi todos los casos los extractos lipídicos mejoraban el aprovechamiento del alimento, pero no tanto como el aceite de arenque corriente. Los extractos de harinas tratadas con antioxidantes se aprovechaban un poco mas eficazmente que los de harinas no tratadas. Aproximadamente un 10% de lípidos inextractables quedaban en las harinas no tratadas almacenadas, pero los datos indican que no se utiliza en la nutrición.

El informe detallado se ha publicado como: Circular No. 25, Technological Station, Fisheries Research Board of Canada, Vancouver 8, B.C.

DISCUSSION

Dr. O. R. Braekkan (Norway):—

There seems to be an error in the thiamin content reported for raw and cooked fish in Table III of Bramsnaes' paper. It is important to use the greatest care in employing chlorinated solvents, since the residue may damage liver tissues. This problem needs to be considered in any research using fish meal.

Mr. F. Bramsnaes (Denmark): It may be that the reported data do not take into account the presence of thiaminase.

On Dr. Cutting's paper, Dr. B. C. Guha (India) asked: Have any attempts been made to cut down the losses of nutritive material, which may be as high as 75 per cent under the traditional method of processing fish? If this otherwise lost material could be recovered for fish meal production, if not human food, a great loss would be eliminated. Increased fish consumption would be thus promoted.

Dr. C. L. Cutting (U.K.): Fish waste is high in nutritive value; but with present methods recovery of these nutrients is not economical. In reference to dried fish, insect contamination resulted in loss of nutritive value. It is important not to eliminate traditional products in countries where they have been successfully evolved and fit in with the received pattern of nutrition. But fish technologists can contribute to the formation of standards of processing and products to reduce wastage and to improve quality, prevent adulteration, minimize insect infestation, etc.

Dr. E. Hess (U.K.): It is difficult to compare the quantities of fish available for consumption in different countries in the absence of information on the technological losses in handling and processing of various products. It is difficult in developing countries, where fish may be landed in relatively small quantities in scattered fishing centres, to make use of such technological losses (including offal) where fish meal production is uneconomical (fish silage, fermented products, etc.).

On Dr. Amano's paper, Dr. M. M. A. Kader (U.A.R.) objected: The terms "putrifaction" and "fermentation" need to be clarified.

Dr. C. L. Cutting (U.K.): Although fermented products are high in ammonia content, nevertheless people in South-east Asia are in fact consuming this food; it would therefore be unwise to change the title of the paper to putrifaction.

Dr. K. Amano (Japan): It must be borne in mind that fermentation also results from enzymatic action, not only from microbiological decomposition.

Dr. R. Sinnhuber (U.S.A.): Has Dr. Amano found histamine in fermented fish products?

Dr. K. Amano (Japan): There is some evidence that histamine is formed in certain fermented and dried fish, such as tuna.

Dr. A. J. van Veen (FAO): The amounts of histamine in dried tuna can sometimes be very great. But almost all fermented products contain at least small quantities of histamine.

Dr. N. B. Thanh (Viet-Nam): Fish sauce is made of fresh fish which are subject to autolytic action. Though fermented, the product is rich in amino acids. The bacteria are not pathogenic; they are in fact beneficial. In Viet-Nam there are regulations concerning the processing of fermented products.

Dr. C. L. Cutting (U.K.): It is better to have "half the fish than nothing at all". It is true that new methods are needed to improve the quality and handling of fish; nevertheless, we have to work with what we have for the present. Perhaps if we add spices, we might make a more desirable or acceptable product.

Dr. E. Hess (U.K.): More information is needed on the losses which result from handling or processing, especially in developing countries. The quantity of fish consumed in these countries is usually small, chiefly because their fishing ports or landing stations are widely scattered, and transport is both scarce and expensive. It is important to reduce further losses which may occur through technological processing.

Dr. K. K. P. N. Rao (FAO): Estimates of consumption should certainly take into account losses or wastage of fish supplies in processing or in transport, in addition to the amount of food actually consumed. This is already done in the case of FAO Food Balance Sheets, which form the basis for the data which I shall be presenting later on in my paper under Part III. I note that in the introduction to Dr. Amano's paper it was said that the nutritive contribution of fermented fish products to the diets of the people in the Far East is significant. While this is true, the actual contribution is not very much; in most of the Far Eastern countries it is even less than the example quoted for Viet-Nam. Therefore, it would be very useful if the nutritive value of such produce could be increased, so that a greater contribution of nutrients might be made to the diets. Dr. Amano's views on the possibilities in this direction would be appreciated.

Dr. K. Amano (Japan): In my view no significant increase could be made in the consumption of fermented fish; acceptability is limited by their salt content. Application of refrigeration and other technological improvements would be necessary if the consumption of fishery products were to be increased.

Prof. A. M. Leroy (France): It is generally recognized that processing certain fish sauces leads to losses in amino acids; nevertheless, these fermented products do provide protein for people who urgently need it. We must keep in mind the seasoning effect of fish autolysates in the Far East, whose main object is to encourage the consumption of rice in considerable quantities. Although this effect is obtained at the cost of amino acids in the raw material which is used (notably of lysine and methionine), it none the less justifies the large-scale use of these products. Indeed it might be well worth studying their manufacturing with a view to perfecting the process in order to reduce the degree of loss. The use of fish autolysates in animal feeding has enabled us to demonstrate by a series of tests the stimulating effect of these products on the animals' appetites.

Dr. C. L. Cutting (U.K.): Much can be done to improve the quality of these fermented products through the application of modern technology. People in the Far East are already setting up standards for the salt, ammonia, and nitrogen content of these products.

On Dr. Morrison's paper, Dr. G. M. Dreosti (South Africa) observed: The product discussed in Morrison's paper was not really fish flour, because it was produced by using a high-pressure hexane extraction method which damaged the protein. Studies on FIRI fish flour show that it possesses a biological value of 80–85 per cent, depending on samples used. Universally good results in reducing malnutrition have been obtained by using FIRI fish flour.

Dr. K. J. Carpenter (U.K.): The low figure of 29 for the NPU value of fish flour gives the wrong impression. The flour was probably a commercial meal which would not be suitable for human consumption. The use of sustained heat to remove residual chlorinated hydrocarbons, employed in azeotropic drying, may cause more damage to the protein than would occur if other solvent drying methods, requiring only a flash high temperature drying, were employed.

Dr. A. B. Morrison (Canada): Flour produced by chloroform flotation is not toxic when fed at low protein levels, but is toxic at high levels.

On Dr. Shewan's paper, Dr. R. Sinnhuber (U.S.A.) asked: Am I to understand that crab meat can be satisfactorily irradiated at levels of 4·5–5·0 megarads? One megarad is the limit for Pacific crab meat. Possibly high vacuum or low temperatures might allow treatment at higher levels of megarads. These techniques are limited, because enzyme inactivation has to be accomplished by heating. Another problem is the lack of a suitable container. Irradiation, rather than toluene, may be a useful tool to study autolysis. Irradiated products should be compared with canned rather than with fresh products.

Dr. O. R. Braekkan (Norway): Niacin is destroyed by irradiation; I am curious to know what happens to the amino acids.

Dr. J. M. Shewan (U.K.): According to current reports on essential amino acids, the maximum destruction is 10 per cent.

Prof. A. M. Leroy (France): If heavier levels of irradiation are used, it might be possible to stabilize offal for use in animal feeding.

Dr. G. Borgström (U.S.A.): Better results could be obtained by lowering the temperature of the irradiated product to 30°F, just short of freezing. It is necessary to treat most of the figures which are published on the effect of "radio-pasteurization" with some reserve, for they often give a rather exaggerated account of the efficacy of this process: this is particularly true of the treatment of sea food, with its dominant psychrophili flora.

Dr. J. M. Shewan (U.K.): The first thing to determine was whether the public would in fact prefer irradiated fish to fresh fish. My own panels have found that fish irradiated at levels above 2·5 megarads are not acceptable.

Dr. R. Sinnhuber (U.S.A.): Whilst certain fish could indeed be irradiated at high levels, yet other fishery products do not stand up very well when this technique is used.

Dr. H. S. Olcott (U.S.A.): Will Dr. Shewan comment on the oxidation of lipids resulting from irradiation?

Dr. J. M. Shewan (U.K.): There are indeed certain oxidative changes in the lipids, but their importance is unknown. It would seem that a change in taste and smell of fish originates in their fatty portions.

Dr. H. S. Olcott (U.S.A.): Would Dr. Morrison say whether there was any difference in the level of lysine between the two methods of solvent extraction which he had described, and what was the difference in toxicity between flour prepared with ethylene dichloride and flour prepared with chloroform?

Dr. A. B. Morrison (Canada): On the average, iso-propanal extraction gives 25 per cent higher lysine than the other method; I regret that I have no information on the toxicity of ethylene dichloride.

On Dr. Peters' paper, Dr. F. A. L. Bramstedt (Germany) remarked: In some of my work methionine sulfoxide has been found to occur only irregularly. This suggested that its occurrence may require the presence of some specific microbial flora. Has Dr. Peters noticed any regular occurrence of methionine sulfoxide?

Dr. J. A. Peters (U.S.A.): I have tested for methionine sulfoxide in only one series, and for one species. In this case it occurred only at the later stages of spoilage.

On Mrs. Kurtzman's paper, Mr. H. Loredo (Mexico) intervened to say: In Mexico, fish meal is made from the heads and legs of shrimps, and commands a good market. This product, however, contains a considerable quantity of chitin, which has inferior nutritive value. But this is of little consequence, since it is used mostly for spicing. Is it possible that the fish flour mentioned by Dr. Kurtzman, which has high protein content, has some chitin in it?

Mrs. C. Kurtzman (U.S.A.): None of our fish flour is made from crustaceans and therefore no chitin is ever present. We did carry out digestibility work on some of our samples using rats as test animals. A value for apparent digestibility was found which did not vary much from one sample to the other. In earlier work, however, when shark fish flour, which contained urea, was tested, a somewhat lower value was found.

Mr. F. Bramsnaes (Denmark): I am much surprised that the bone protein should be thought to be equal to flesh protein, especially since the flour made from the whole fish was of lower protein quality than that from which the bone was absent.

Mrs. C. Kurtzman (U.S.A.): Our investigations showed no statistically significant decrease in quality of the bone proteins.

On Dr. Okada's paper, Dr. C. L. Cutting (U.K.) observed: I have myself tasted Japanese fish sausage and found it excellent. I wonder whether the preservative "nitrofurane" had to be added, or whether it might be eliminated by the use of better handling conditions in the plant. What should be the shelf life of the fish sausage in winter and summer, with and without refrigeration, and with or without preservative?

Dr. M. Okada (Japan): It should first be understood that, whereas regulations in Japan permit the use of nitrofurane as a preservative, we are certainly not suggesting that this preservative should be used in countries in which such approval has not been made. The sanitary conditions in our fish sausage plants are quite good. Without refrigeration the storage life of fish sausage is about one week in winter, and about 3–4 days in summer if a preservative is not employed. When refrigeration is used, the storage life is 2–3 weeks. Use of refrigeration is not practical in our country, because so many of our retail outlets do not have refrigeration facilities. Therefore, at least in the summer, preservatives are necessary.

Dr. R. Kreuzer (FAO): Fish sausage in Japan is made in a similar way to meat sausage in Germany and other countries, and has a keeping time similar to meat sausage. In countries where preservatives are not permitted, fish sausage has to be kept under refrigeration like meat sausage. It is possible however to make a fish sausage in salami style which keeps well for a considerable time without preservatives or refrigeration. So far as I was able to observe, sanitary and handling conditions in the new Japanese fish sausage factories were excellent. The raw material used was of good quality also. I strongly recommend this type of product as a means of bringing fish protein to the people. I believe that it is possible to keep the price within the lower ranges of purchasing power.

Mr. R. Finch (U.S.A.): Sausage made from tuna keeps for 2–3 weeks with refrigeration. This is comparable with meat sausage. Tuna sausage can also be kept for longer periods of time by freezing. With frozen sausage, however, rancidity is a problem, and antioxidants may have to be used. I should like to know whether, during mixing of fish sausage in Japan, refrigeration with ice or otherwise was used.

Dr. M. Okada (Japan): In some plants cooling with ice was usual during the mixing process.

Summary

In summing up the discussion **Dr. R. Kreuzer** (FAO) drew attention to the need for technological data concerning handling, storage, processing, and distribution of fish, especially in tropical countries where the use of such data will give immediate results. Such work should provide data to improve traditional methods of fish utilization and stimulate product development, with or without modern equipment.

Moreover, in most of the countries under consideration, there is a need for skilled persons to organize and train a fisheries staff. Training facilities in the developing countries need to be supplemented by the establishment of Technical Schools in countries with developed fisheries industries, where persons of developing countries can come for advanced training. These highly trained persons would then return to their respective countries both as project leaders in fishery development and as teachers for local training.

Mr. J. Adjetey (Ghana) fully agreed with Dr. Kreuzer's recommendations. He added that Ghana, along with the other developing countries, was trying to improve the conditions of its fisheries. It was equally important, however, to improve at the same time the economics of processing, so that all fish products are brought within the purchasing power of people. He urged that this group should seriously consider this recommendation.

From the offal of herrings in packing plants of Scotland, Iceland, Norway, and many other countries, together with surplus whole fish, fine quality herring meal is made for use in stock foods.

PART III

CONTRIBUTION OF FISH AND FISH PRODUCTS TO NATIONAL DIETS

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Section 1 : GENERAL

FOOD INTAKE, NUTRITION REQUIREMENTS AND INCIDENCE OF MALNUTRITION

by

K. K. P. N. RAO

Sufficient evidence exists to say that more than one-half the earth's population is undernourished or malnourished. The great contrasts in world levels of food and nutrition are here illustrated in eight tables summarizing relevant data from national food balance sheets and dietary surveys. In critical areas (Asia and the Far East, Near East, Africa and Latin America), prevalence of disease involving nutritional deficiencies can be directly related with poor food supplies.

Generally, (a) diets show satisfactory energy content, though there are periodic serious caloric shortages in some areas; (b) food supplies are too rich in carbohydrate, and too poor in nutrients essential to good health; (c) this can be corrected only by consumption of protective foods like pulses, milk, meat, eggs and fish.

The specific rôle of fish in diets is discussed. Regional variations in fish consumption are shown. Although fish contributes only a small percentage to total caloric intake, it has a great potential use in the relief of protein malnutrition which is the most serious nutrition problem in the critical areas.

Calcium intake from fish is generally unimportant except in a few countries. Limited data are provided which indicate that fish could provide more thiamine and riboflavin than at present. Only a few countries obtain substantial fat intake from fish, but even lesser intakes are considered to be of interest.

Estimates are given of percentage increases of food required to make even limited nutritional improvement in average diets over 25 years, taking into account the fast increasing populations. The figures for fish are: 90 per cent generally, 120 per cent for Asia and the Far East, 130 per cent for the Near East. Five references are given.

CONSOMMATION ALIMENTAIRE, EXIGENCES NUTRITIONNELLES ET INCIDENCE DE LA MALNUTRITION

Il y a déjà bien assez des preuves peur affirmer que plus de la moitié de la population mondiale souffre de sous-alimentation et de malnutrition. Les grands contrastes de niveaux alimentaires et nutritionnnels dans le monde sont illustrés ici par huit tableaux qui résument les principales données obtenues depuis les bilans alimentaires nationaux et des études sur la nutrition.

Dans des régions critiques (Asie et Extrême-Orient, Proche-Orient, Afrique et Amérique Latine), l'incidence des maladies mettant en cause des déficiences nutritionnelles peut être directement rattachée à des ressources alimentaires pauvres.

D'une façon générale, (a) les régimes alimentaires présentent une valeur énergétique satisfaisante, quoi qu'il y ait une pénurie periodique sérieuse en calories dans quelques régions; (b) les ressources alimentaires sont trop riches en glucides et trop pauvres en éléments nutritifs indispensables à la santé; (c) ce désequilibre ne peut être corrigé que par une consommation augmentée d'aliments protecteurs tels que les légumineuses, le lait, la viande, les oeufs et le poisson.

On commente le rôle spécifique du poisson dans les régimes. On présente les variations par régions de la consommation de poisson. Bien que le poisson ne contribue qu'en faible pourcentage à la consommation totale de calories, il présente un usage potentiel important au regard de la malnutrition protéique qui, dans les régions critiques, est le problème alimentaire le plus sérieux.

L'apport en calcium depuis le poisson a peu d'importance sauf dans quelques pays. Des données limitées qu'on a pu réunir montrent que le poisson pourrait fournir plus de thiamine et de riboflavine qu'ils ne font actuellement. Seuls quelques pays dérivent du poisson un apport substantiel en graisses; mais même des apports plus faibles sont considérés comme intéressants.

On présente des estimations concernant les accroissements en pourcentage de la nourriture qu'exige une amélioration nutritionnelle, même limitée, dans les régimes alimentaires moyens, sur 25 ans, et en tenant compte des populations à croissance démographique rapide. Les chiffres pour le poisson sont: 90% d'une façon générale, 120% pour l'Asie et l'Extrême-Orient, 130% pour le Proche-Orient.

Cinq références bibliographiques.

CONSUMO DE ALIMENTOS, NECESIDADES NUTRITIVAS E INCIDENCIA DE LA MALNUTRICION

Existen pruebas suficientes para afirmar que más de la mitad de la población de la tierra está desnutrida o malnutrida. El gran contraste entre el consumo de alimentos y la nutrición se expone aqui en ocho tablas que resumen los datos más importantes de las hojas de balance de alimentos nacionales y de encuestas alimenticias. En las regiones críticas (Asia y el Extremo Oriente, el Medio Oriente, Africa y América Latina), la prevalencia de enfermedades causadas por deficiencias nutritivas puede relacionarse directamente con escasez de alimentos.

Generalmente: (a) las alimentaciones son satisfactorias desde el punto de vista de la energía, pero en algunas regiones existen graves escaseces calóricas periódicas; (b) los alimentos son demasiado ricos en hidratos de carbono y demasiado pobres en los elementos nutritivos esenciales para mantener una buena salud; (c) esta situación se tiene que corregir consumiendo más alimentos protectores como leguminosas, leche, carne, huevos y pescado.

Se discute el papel específico del pescado en la alimentación. Se dan a conocer variaciones regionales en el consumo de pescado. Aunque el pescado aporta solamente un pequeño porcentaje del total de calorías, tiene grandes usos posibles en el alivio de la malnutrición proteica, que es el problema de nutrición más grave en las regiones críticas.

La absorción de calcio a partir del pescado es generalmente de poca importancia excepto en unos cuantos países. Se dan algunos datos que indican que el pescado podría suministrar más tiamina y riboflavina que en la actualidad. Sólo unos pocos países obtienen un importante suministro de grasas del pescado, pero aun los consumos más pequeños se consideran de interés.

Se dan estimaciones de los porcentajes del aumento de alimentos necesario para lograr incluso pequeñas mejoras nutritivas en las alimentaciones normales durante los próximos 25 años, teniendo en cuenta el rápido incremento demográfico. Los datos para el pescado son: 90% en general; 120% en Asia y el Lejano Oriente; 130% en el Medio Oriente. Se dan 5 citas bibliográficas.

Fish in Nutrition: Contribution to National Diets

IT has been estimated that more than one half of the world's population suffers from varying degrees of undernutrition and malnutrition. While a more precise estimate is not yet possible owing to lack of sufficient data from many parts of the world, there is enough evidence already to justify such a conclusion. In view of the close and direct link between the nutritional status of a population and its health and efficiency, the serious implications of this unsatisfactory situation are obvious. Especially in the light of the tremendous population growth, which is taking place now, the problem of providing adequate nutrition for all is certainly one of the most pressing problems facing mankind today. Indeed it is considered by many authorities as the most serious of all, next only to the question of survival from a nuclear holocaust. Although the problem is thus serious enough, even taking the world as a whole, it is particularly serious in those regions which are already short of food, but in which the populations are increasing by leaps and bounds. Thus the problem needs to be viewed on a regional, and even on a national, rather than on a world, basis. For instance, the nutritional defects observed in North America arise generally from over consumption, whereas those observed in Asia and the Far East arise mostly from under consumption, especially of the protective foods. The strong contrasts in the food and nutritional situation prevailing in different regions and countries are clearly illustrated by Tables I–VIII, which summarize relevant data derived from national food balance sheets as well as dietary surveys of various sections of the population in selected countries.

The countries which are facing critical food and nutritional situations are mostly in the regions which are often described as developing or underdeveloped economically: Asia and the Far East, Near East, Africa and Latin America. These regions, therefore, deserve special consideration from the nutritional point of view. In Asia and the Far East, the situation has been recently reported in the following terms: "As for the nutritional quality of average diets, they are in general ill-balanced and defective according to modern nutritional principles. . . . This is confirmed by the wide prevalence of signs of nutritional deficiency, such as protein malnutrition, vitamin A deficiency, beriberi, nutritional anaemias, and ariboflavinosis" (1).

The situation has been described in very similar terms

TABLE I

Food supplies available for human consumption in selected countries in different regions for recent years (based on food balance sheets)

									Fish				
Country	Cereals	Starchy roots	Sugar	Pulses and nuts	Vege-tables	Fruits	Meat and poultry	Eggs	Fresh	Dried and salted	Canned	Milk and prod.	Fats and oils
						g. per capita per day							
EUROPE													
Denmark . .	228·0	331·3	134·5	14·0	183·3	124·7	197·7	21·4	33·4*	7·4	3·0	629·5	76·1
Finland . .	303·8	251·4	110·9	5·3	58·8	86·5	87·1	20·9		[1]31·0*		983·4	62·0
France . .	294·2	269·5	88·2	17·5	350·0	134·4	195·4	29·5		[1]29·7		519·3	47·3
Italy . . .	388·0	129·1	52·6	31·2	372·9	220·0	68·6	23·0	12·6	3·3	2·5	320·1	43·1
Norway . .	218·6	258·5	110·5	10·0	97·7	155·8	100·3	21·3	85·1	[1]7·7	[1]11·6	699·7	67·9
NORTH AMERICA													
Canada . .	194·8	185·5	132·6	13·4	199·7	175·3	202·7	46·6	8·5*	2·2*	5·8	719·0	58·6
U.S.A. . .	184·5	125·9	131·5	19·4	265·5	215·0	219·3	55·0	7·3*	0·7	5·2	721·9	61·4
LATIN AMERICA													
Argentina . .	288·4	258·4	86·7	5·5	125·1	200·2	333·2	24·1		[1]11·3		386·6	40·5
Chile . . .	287·4	277·0	100·4	36·8	211·6	84·9	70·6	10·8		[1]81·9		235·3	21·2
NEAR EAST AND AFRICA													
Israel . . .	338·7	113·1	75·3	22·4	336·4	323·9	70·9	53·2	[2]23·0	[3]8·2		416·5	47·4
Turkey . .	559·3	113·4	31·1	36·9	211·7	202·5	40·4	4·6	3·8	1·6		197·0	18·7
Union of S. Africa	419·9	32·6	128·5	11·4	105·2	119·7	124·6	8·2	13·1*	5·7	2·4	235·9	17·2
United Arab Rep. Egyptian Region	514·1	25·1	48·6	33·2	293·7	174·9	38·8	3·3	14·5*	0·5	0·8	118·9	14·3
ASIA AND THE FAR EAST													
India . . .	339·7	29·2	41·9	63·4	[4]44·6	32·9	4·1	0·6		[1]6·5		123·4	9·9
Japan. . .	414·1	127·7	37·7	86·2	198·6	57·9	12·7	10·6		[1]59·7*		48·7	9·3
OCEANIA													
Australia . .	240·3	146·2	147·4	12·1	167·4	189·9	319·5	28·8	7·7	1·1	3·0	520·6	50·1
New Zealand .	235·4	160·4	130·3	10·8	192·5	161·5	287·6	42·5	16·6*		2·9	776·8	65·3

* Edible portion.

[1] In term of fish, fresh.

[2] Including 17·0 g. of fresh fish (round weight), 0·8 frozen and chilled fish (round weight), 5·2 frozen and chilled fish (edible portion).

[3] And miscellaneous.

[4] Data refers to 1954–56.

in the Near East, where protein malnutrition, anaemia, rickets, pellagra, avitaminosis A, and ariboflavinosis are reported to be prevalent in varying degrees, and this knowledge "is generally in line with the data on food consumption" (2).

In Africa, "protein malnutrition is widespread" as shown by the prevalence of Kwashiorkor, which is the most serious nutritional syndrome in that region, and "the knowledge available on food supply and consumption fits in with the incidence of protein malnutrition" (3).

TABLE II

Calorie content of food supplies available for human consumption in selected countries in different regions for recent years (based on food balance sheets)

										Fish				
Country	Cereals	Starchy roots	Sugar	Pulses and nuts	Vege- tables	Fruits	Meat and poultry	Eggs	Fresh	Dried and salted	Canned	Milk and prod.	Fats and oils	Total calor.
EUROPE														
Denmark														
Cal./cap/day	794	247	518	45	71	74	543	31	44	10	6	358	674	3,415
% total cal.	23·2	7·2	15·2	1·3	2·1	2·2	15·9	0·9	1·3	0·3	0·2	10·5	19·7	100
Finland														
Cal./cap/day	1,063	194	429	18	13	49	198	30		41		631	451	3,117
% total cal.	34·1	6·2	13·8	0·6	0·4	1·6	6·3	1·0		1·3		20·2	14·5	100
France														
Cal./cap/day	1,028	190	340	54	77	68	413	43		18		271	418	2,920
% total cal.	35·2	6·5	11·7	1·8	2·6	2·3	14·2	1·5		0·6		9·3	14·3	100
Italy														
Cal./cap/day	1,369	94	203	89	82	115	117	33	8	7	5	174	381	2,677
% total cal.	51·1	3·5	7·6	3·3	3·1	4·3	4·4	1·2	0·3	0·3	0·2	6·5	14·2	100
Norway														
Cal./cap/day	764	200	428	37	21	80	235	31	53	5	7	509	611	2,981
% total cal.	25·6	6·7	14·4	1·2	0·7	2·7	7·9	1·0	1·8	0·2	0·2	17·1	20·5	100
NORTH AMERICA														
Canada														
Cal./cap/day	688	130	493	63	58	100	547	67	10	5	11	437	463	3,072
% total cal.	22·4	4·2	16·0	2·1	1·9	3·2	17·8	2·2	0·3	0·2	0·4	14·2	15·1	100
U.S.A.														
Cal./cap/day	674	90	491	76	71	111	554	79	10	1	10	425	509	3,101
% total cal.	21·7	2·9	15·8	2·5	2·3	3·6	17·9	2·6	0·3	—	0·3	13·7	16·4	100
LATIN AMERICA														
Argentina														
Cal/cap/day	1,049	195	335	19	29	87	747	35		7		246	346	3,095
% total cal.	33·9	6·3	10·8	0·6	0·9	2·8	24·2	1·1		0·2		8·0	11·2	100
Chile														
Cal./cap/day	1,045	194	388	127	47	37	147	16		51		150	179	2,381
% total cal.	43·9	8·1	16·3	5·3	2·0	1·6	6·2	0·7		2·1		6·3	7·5	100
NEAR EAST AND AFRICA														
Israel														
Cal./cap/day	1,186	94	290	96	72	124	114	77	12	11		233	379	2,688
% total cal.	44·1	3·5	10·8	3·6	2·7	4·6	4·2	2·9	0·4	0·4		8·7	14·1	100
Turkey														
Cal./cap/day	1,960	79	121	140	47	92	66	6	2	3		116	165	2,797
% total cal.	70·1	2·8	4·3	5·0	1·7	3·3	2·4	0·2	0·1	0·1		4·1	5·9	100
Union of S. Africa														
Cal./cap/day	1,487	24	497	42	23	59	294	12	23	14	7	152	139	2,773
% total cal.	53·7	0·9	17·9	1·5	0·8	2·1	10·6	0·4	0·8	0·5	0·3	5·5	5·0	100
United Arab Rep. Egyptian Reg.														
Cal./cap/day	1,820	22	169	120	72	117	59	5	19	2	2	106	127	2,640
% total cal.	69·0	0·8	6·4	4·6	2·7	4·4	2·2	0·2	0·7	0·1	0·1	4·0	4·8	100
ASIA AND THE FAR EAST														
India														
Cal./cap/day	1,196	28	147	196	10	19	6	1		4		105	87	1,799
% total cal.	66·5	1·5	8·2	10·9	0·6	1·1	0·3	0·1		0·2		5·8	4·8	100
Japan														
Cal./cap/day	1,422	160	148	153	61	26	19	16		91		29	84	2,209
% total cal.	64·4	7·2	6·7	6·9	2·8	1·2	0·9	0·7		4·1		1·3	3·8	100
OCEANIA														
Australia														
Cal./cap/day	870	104	577	58	38	85	715	41	5	1	5	328	384	3,211
% total cal.	27·1	3·2	18·0	1·8	1·2	2·6	22·3	1·3	0·2	—	0·2	10·2	11·9	100
New Zealand														
Cal./cap/day	856	117	493	42	42	105	639	61	17		7	558	493	3,430
% total cal.	24·9	3·4	14·4	1·2	1·2	3·1	18·6	1·8	0·5		0·2	16·3	14·4	100

The situation in Latin America has been reported thus: "The most frequently recorded indications of clinical malnutrition revealed by these surveys have been protein deficiencies, avitaminosis A, ariboflavinosis, anaemias and goiter. Evidence has been obtained in some instances of insufficiency of calories and lack of niacin"(4).

Although it must be emphasized that the conditions can differ widely from one country to another, and often within the same country, the general picture in these regions can be summarized as follows:

TABLE III

Protein content of food supplies available for human consumption in selected countries in different regions for recent years (based on food balance sheets)

Country	Cereals	Starchy roots	Pulses and nuts	Meat and poultry	Eggs	Fish			Milk and prod.	Total protein
						Fresh	Dried and salted	Canned		
EUROPE										
Denmark										
g./cap/day . . .	25·1	6·0	2·3	24·0	2·4	6·3	1·4	0·6	22·0	93·2
% total protein . .	26·9	6·4	2·5	25·7	2·6	6·8	1·5	0·6	23·6	100
Finland										
g./cap/day . . .	33·1	4·7	1·1	11·7	2·3		5·8		34·4	94·5
% total protein . .	35·0	5·0	1·2	12·4	2·4		6·1		36·5	100
France										
g./cap/day . . .	32·0	4·6	2·3	26·6	3·0		2·6		18·2	95·1
% total protein . .	33·7	4·8	2·4	28·0	3·2		2·7		19·1	100
Italy										
g./cap/day . . .	38·9	2·3	4·4	9·8	2·5	1·1	1·1	0·5	11·2	77·6
% total protein . .	50·2	3·0	5·7	12·6	3·2	1·4	1·4	0·6	14·4	100
Norway										
g./cap/day . . .	24·6	4·9	1·5	12·5	2·3	7·5	0·7	1·0	24·5	82·0
% total protein . .	30·0	6·0	1·8	15·3	2·8	9·1	0·9	1·2	29·9	100
NORTH AMERICA										
Canada										
g./cap/day . . .	23·1	3·1	2·7	27·9	5·3	1·5	0·9	1·2	25·2	94·4
% total protein . .	24·4	3·3	2·9	29·5	5·6	1·6	1·0	1·3	26·7	100
U.S.A.										
g./cap/day . . .	14·9	2·1	4·4	31·3	6·1	1·4	0·1	1·0	24·8	91·0
% total protein . .	16·4	2·3	4·8	34·4	6·7	1·5	0·1	1·1	27·3	100
LATIN AMERICA										
Argentina										
g./cap/day . . .	30·9	4·1	1·2	48·2	2·6		1·0		13·5	104·2
% total protein . .	29·6	3·9	1·2	46·2	2·5		1·0		13·0	100
Chile										
g./cap/day . . .	30·4	4·7	8·0	10·0	1·2		7·2		8·2	73·2
% total protein . .	41·6	6·4	10·9	13·7	1·6		9·8		11·2	100
NEAR EAST AND AFRICA										
Israel										
g./cap/day . . .	38·9	1·8	4·8	9·3	5·8	2·4	1·2		14·3	83·8
% total protein . .	46·4	2·1	5·7	11·1	6·9	2·9	1·4		17·1	100
Turkey										
g./cap/day . . .	62·5	1·9	7·2	5·6	0·4	0·3	0·3		7·8	89·8
% total protein . .	69·6	2·1	8·0	6·3	0·4	0·3	0·3		8·7	100
Union of S. Africa										
g./cap/day . . .	39·7	0·5	2·5	17·0	0·9	2·6	2·2	0·5	8·3	76·4
% total protein . .	51·9	0·6	3·3	22·2	1·2	3·4	2·9	0·7	10·9	100
United Arab Republic Egyptian Region										
g./cap/day . . .	51·4	0·4	7·4	5·3	0·4	2·7	0·1	0·3	4·5	78·3
% total protein . .	65·7	0·5	9·5	6·8	0·5	3·4	0·1	0·4	5·7	100
ASIA AND THE FAR EAST										
India										
g./cap/day . . .	27·9	0·4	11·9	0·5	0·1		0·6		4·6	46·8
% total protein . .	59·6	0·9	25·4	1·1	0·2		1·3		9·8	100
Japan										
g./cap/day . . .	31·9	1·8	12·5	2·8	1·4		11·3		1·5	66·7
% total protein . .	47·8	2·7	18·8	4·2	2·1		16·9		2·3	100
OCEANIA										
Australia										
g./cap/day . . .	23·8	2·5	2·2	37·4	3·3	0·9	0·2	0·6	17·5	91·3
% total protein . .	26·1	2·7	2·4	40·9	3·6	1·0	0·2	0·7	19·2	100
New Zealand										
g./cap/day . . .	25·6	2·7	1·5	35·7	4·7	3·0		0·6	27·8	105·5
% total protein . .	24·3	2·6	1·4	33·8	4·5	2·8		0·6	26·3	100

(*a*) the average diets are generally satisfactory from the viewpoint of their energy content, although shortages of calories are known to be quite serious from time to time in some areas;

(*b*) food supplies in general are very defective in their nutritional quality since they contain too much of foods rich in carbohydrate, which may contribute as much as 70–90 per cent of total calorie intakes, and too

TABLE IV

Calcium content of food supplies available for human consumption in selected countries in different regions for recent years (based on food balance sheets)

Country and year	Cereals	Starchy roots	Pulses and nuts	Vege- tables	Fruits	Meat and poultry	Eggs	Fish	Milk and prod.	Total supply of Ca
EUROPE										
Denmark (1957/58)										
mg. Ca/cap/day	61	25	13	94	17	16	9	16	749	1,000
% of total Ca supply	6	3	1	9	2	2	1	2	74	100
Finland (1958/59)										
mg. Ca/cap/day	70	19	3	30	11	7	9	10	1,170	1,329
% of total Ca supply	5	1		2	1	1	1	1	88	100
France (1958/59)										
mg. Ca/cap/day	46	19	13	179	18	17	13	8	618	930
% of total Ca supply	5	2	1	19	2	2	1	1	67	100
Italy (1958/59)										
mg. Ca/cap/day	59	9	24	190	26	6	10	5	381	710
% of total Ca supply	8	1	3	27	4	1	1	1	54	100
Norway (1958/59)										
mg. Ca/cap/day	52	20	9	50	23	8	9	22	833	1,026
% of total Ca supply	5	2	1	5	2	1	1	2	81	100
NORTH AMERICA										
Canada (1957/58)										
mg. Ca/cap/day	34	13	12	64	24	17	21	6	856	1,047
% of total Ca supply	3	1	1	6	2	2	2	1	82	100
U.S.A. (1958)										
mg. Ca/cap/day	29	10	18	135	21	18	24	5	856	1,116
% of total Ca supply	3	1	2	12	2	2	2		76	100
LATIN AMERICA										
Argentina (1957)										
mg. Ca/cap/day	45	28	5	44	27	29	11	2	460	651
% of total Ca supply	7	4	1	7	4	5	2	—	70	100
Chile (1957)										
mg. Ca/cap/day	45	19	34	108	11	6	5	12	280	520
% of total Ca supply	9	4	7	20	2	1	1	2	54	100
NEAR EAST AND AFRICA										
Israel (1957/58)										
mg. Ca/cap/day	80	8	37	172	53	6	23	9	496	884
% of total Ca supply	9	1	4	19	6	1	3	1	56	100
Turkey (1957/58)										
mg. Ca/cap/day	125	8	35	108	30	4	2	1	234	547
% of total Ca supply	23	1	6	20	6	1	—	—	43	100
Union of S. Africa (1958)										
mg. Ca/cap/day	53	3	10	54	19	11	4	8	280	442
% of total Ca supply	12	1	2	12	4	2	1	2	64	100
United Arab Republic Egyptian Region (1957/58)										
mg. Ca/cap/day	87	3	31	140	35	4	2	5	142	449
% of total Ca supply	19	1	7	31	8	1	—	1	32	100
ASIA AND THE FAR EAST										
India (1957/58)										
mg. Ca/cap/day	98	6	67	23	5			1	147	347
% of total Ca supply	28	2	19	7	1	—	—	—	43	100
Japan (1958)										
mg. Ca/cap/day	66	22	91	101	5	1	5	19	58	368
% of total Ca supply	18	6	25	28	1	—	1	5	16	100
OCEANIA										
Australia (1958/59)										
mg. Ca/cap/day	39	11	10	85	37	26	1	4	620	833
% of total Ca supply	5	1	1	10	4	3		1	75	100
New Zealand (1958)										
mg. Ca/cap/day	40	13	11	98	29	23	19	6	926	1,165
% of total Ca supply	3	1	1	8	3	2	2	1	79	100

little of protective foods rich in proteins and other nutrients; and

(*c*) consequently nutritional deficiencies, of which protein malnutrition is by far the most serious, are widely prevalent in varying degrees of seriousness, and can be corrected most effectively by increased consumption of protective foods, such as pulses, milk, meat, eggs and **fish.**

TABLE V

Fat content of food supplies available for human consumption in selected countries in different regions for recent years (based on food balance sheets)

Country	Cereals	Pulses and nuts	Meat and poultry	Eggs	Fish			Milk and prod.	Fats and oils	Total fat
					Fresh	Dried and salted	Canned			
EUROPE										
Denmark										
g./cap/day	4·2	1·1	49·2	2·2	1·9	0·3	0·2	23·1	76·1	159·3
% of total fat	2·6	0·7	30·9	1·4	1·2	0·2	0·1	14·5	47·8	100
Finland										
g./cap/day	4·8	0·1	16·4	2·2		1·8		34·5	50·9	111·3
% of total fat	4·3	0·1	14·7	2·0		1·6		31·0	45·7	100
France										
g./cap/day	4·1	2·0	33·0	3·0		0·8		15·7	47·3	107·3
% of total fat	3·8	1·9	30·7	2·8		0·7		14·6	44·1	100
Italy										
g./cap/day	5·4	2·0	8·1	2·4	0·3	0·3	0·3	10·3	43·1	73·8
% of total fat	7·3	2·7	11·0	3·3	0·4	0·4	0·4	14·0	58·4	100
Norway										
g./cap/day	3·7	1·8	20·6	2·2	2·3	0·2	0·3	32·2	67·9	132·1
% of total fat	2·8	1·4	15·6	1·7	1·7	0·2	0·2	24·4	51·4	100
NORTH AMERICA										
Canada										
g./cap/day	2·8	3·9	47·4	4·8	0·4	0·1	0·6	22·8	52·0	135·8
% of total fat	2·1	2·9	34·9	3·5	0·3	0·1	0·4	16·8	38·3	100
U.S.A.										
g./cap/day	2·2	3·2	46·7	5·7	0·4	—	0·6	23·0	57·3	140·4
% of total fat	1·6	2·3	33·3	4·0	0·3	—	0·4	16·4	40·8	100
LATIN AMERICA										
Argentina										
g./cap/day	3·1	0·2	60·0	2·5		0·3		14·4	38·9	120·6
% of total fat	2·6	0·2	49·8	2·1		0·2		11·9	32·2	100
Chile										
g./cap/day	3·0	1·1	11·7	1·1		2·2		8·3	20·1	48·2
% of total fat	6·0	2·3	24·4	2·3		4·6		17·2	41·8	100
NEAR EAST AND AFRICA										
Israel										
g./cap/day	5·0	5·6	8·3	5·5	0·2	0·6		12·4	43·2	82·7
% of total fat	6·0	6·8	10·0	6·7	0·2	0·7		15·0	52·3	100
Turkey										
g./cap/day	9·8	4·3	4·4	0·4	0·1	0·1		6·3	18·7	45·6
% of total fat	21·5	9·4	9·7	0·9	0·2	0·2		13·8	41·0	100
Union of South Africa										
g./cap/day	13·2	0·8	24·5	0·8	1·3	0·6	0·6	8·4	15·5	66·6
% of total fat	19·8	1·2	36·8	1·2	2·0	0·9	0·9	12·6	23·3	100
United Arab Republic Egyptian Region										
g./cap/day	12·0	1·9	4·0	0·3	0·8	0·1	0·1	7·4	14·3	42·2
% of total fat	28·5	4·5	9·5	0·7	1·9	0·2	0·2	17·5	33·9	100
ASIA AND THE FAR EAST										
India										
g./cap/day	4·8	2·6	0·4	0·1		0·2		7·1	9·9	25·3
% of total fat	19·0	10·3	1·6	0·4		0·8		28·0	39·1	100
Japan										
g./cap/day	4·5	4·3	0·8	1·2		3·2		1·6	9·3	25·6
% of total fat	17·6	16·8	3·1	4·7		12·5		6·2	36·3	100
OCEANIA										
Australia										
g./cap/day	3·8	4·4	61·8	2·9	0·1	—	0·2	19·2	42·5	135·1
% of total fat	2·8	3·3	45·7	2·1	0·1	—	0·1	14·2	31·5	100
New Zealand										
g./cap/day	2·9	2·7	55·0	4·4	0·4		0·4	30·5	55·4	153·3
% of total fat	1·9	1·7	35·8	2·9	0·3		0·3	19·9	36·1	100

After this exposé of the major nutritional defects in the average diets in the under-fed regions of the world and the general lines for their improvement, it will now be appropriate to look at the specific rôle of fish in this connection. From Table I it can be seen that the average quantities of fish consumed in different countries vary exceedingly, ranging from less than 10 g. per caput per day in Turkey to more than 100 g. in Norway. Moreover, Table VI will show that fish consumption can vary considerably even within the same country; e.g. in Northern Nigeria fish consumption is very low or even negligible, while in Southern Nigeria very much greater quantities are consumed. These differences in the quantities of fish consumed are naturally reflected in the contributions which fish make to the intakes of calories and nutrients. With respect to calories, fish are of no practical importance, since they contribute only very small percentages of the total calorie intakes (as shown in Table II). In any case, as pointed out already, calorie shortage is not the major defect of the diets in general, even in the ill-fed regions of the world. In regard to protein, on the other hand, the picture is quite different. As emphasized earlier, protein malnutrition is the major defect in most of the developing regions, and it is here that fish can make an outstanding contribution to the nutritional improvement. It can be seen from Table III that the supplies of high-quality protein of animal origin in the developing regions are far below those in the well-developed regions: e.g. less than 6 g. per caput per day in India, as compared with more than 60 g. in U.S.A. The same table (and also Table VII) will show that the amounts of protein contributed by fish are generally low in the developing regions, both in absolute quantities and in relative proportions. For instance, in the Egyptian region, only 3 g., or about 4 per cent of total protein, are derived from fish. Thus it is clear that fish could play a much greater rôle than they do now in the developing regions, in raising their very low intakes of high-quality protein and thereby eradicate the ravages of protein malnutrition.

TABLE VI

Average quantities of foods consumed in selected countries in different regions (based on dietary surveys)

Country	Cereals	Starchy roots	Sugar	Pulses and nuts	Vegetables	Fruits	Meat and poultry	Eggs	Fish			Milk and prod.	Fats and oils	
						g./capita/day								
EUROPE														
United Kingdom	224	237	83	[1]127		[2]110	143	35	25			426	48	
NEAR EAST AND AFRICA														
Israel . .	291	104	64	13	246	274	55	45	15			336	35	
Ivory Coast														
Village . .	31	1,746	1	37	40	21	66	—	19			—		
Camp . .	19	2,032	1	58	56	62	98	—	17			—	–	
									Raw fish	Dried fish				
ASIA AND THE FAR EAST														
Japan[3] . .	438	41	10	58	216	20	4	2	44	14		12	6	
OCEANIA														
Cook Islands (Rarotonga) .	264	675	16	239	15	51	86	—	[4]260			3	11	
									Fresh fish	Dried fish				
LATIN AMERICA														
Peru . . .	104	130	53	56	18	380	55	6	50	15			13	
Argentina									Fresh fish	Canned fish				Alcohol. beverages
Barranqueras y Puerto Vilelas	317	150	80	4	175	81	231	25	1	2		160	30	132
Resistencia .	343	137	69	4	152	83	187	18	4	2		198	36	155
NEAR EAST AND AFRICA									Freshwater, dried					
North Nigeria[5]														
Bida farmers .	547	176	—	40	22	180	4	—	8			—	21	
Kontagora farmers	732	24	—	75	15	77	3	—	1			5	5	
Zuru farmers .	801	24	[6]6	61	28	46	2	—	1			16	1	
Southern Nigeria[5]									Fresh	Dr.	Can.			
Warri traders .	186	511	34	28	36	118	132	10	62	30	3	33	41	
Illu farmers .	36	1,011	3	18	10	19	38	—	18	18	—	–	35	
Soragbemi fishermen	15	449	4	1	6	13	—	—	[7]165	79	—	—	27	

[1] Including "vegetables (fresh and green) (58·1)" and "other vegetables and pulses (68·4)".
Including tomatoes.
[3] Survey on food consumption on the people in Tokyo living on salaries (March 1944). Intake per adult.
[4] Including "non fatty fishes (254)" and "molluscs (6)".
[5] Survey of adults (over 12 years of age).
[6] Sugar cane, stem.
[7] Also prawns (fresh): 4; oysters (local): 7.

Apart from the very serious problem of protein malnutrition, there are also other nutritional deficiencies, which are prevalent in many parts of the world, as indicated earlier. It would be of interest, therefore, to consider here the rôle of fish in relation to some of the essential minerals and vitamins. Table IV will show that the contribution of fish to total calcium intakes, considered on a national average basis, is generally unimportant, and does not exceed 5 per cent even in those countries where fish consumption is high. On the other hand, Table VIII will show clearly that, within individual countries, some sections of the population might be obtaining very substantial parts of their calcium intakes from fish. For instance, in the Ivory Coast, Peru and parts of Nigeria, as much as a half of the calcium intakes are contributed by fish. Since fish, especially shellfish and small fish eaten with bones, are rich sources of calcium, they can often play an important rôle in providing necessary amounts of calcium in the diets. With respect to thiamine, which is often deficient in the diets of those who subsist mainly on milled white rice, Table VIII includes a limited amount of data to show that fish could make important contributions to thiamine intakes, although in many cases they may not be doing so at present. For instance, in the Cook Islands, 10 per cent of total thiamine intake is obtained from fish, while in many other instances the corresponding figure is less than 1 per cent. The same Table includes also some data on the rôle of fish as a contributor of riboflavin, which is often deficient in the diets of the people in the developing regions, especially of the lower income groups. The situation with respect to riboflavin is somewhat similar

TABLE VII

Protein and fat content of average quantities of fish and products consumed in selected countries in different regions (based on dietary surveys)

	Protein			Fat		
Country	g./cap/day	% of total protein	% of animal protein	g./cap/day	% of total fat	% of animal fat
EUROPE						
United Kingdom	3·0	4·0	7·2	1·1	1·0	2·0
NEAR EAST AND AFRICA						
Israel	2·6	3·4	8·0	0·6	1·0	3·0
Ivory Coast						
Village	10	16·4	40·0	2	10·5	28·6
Camp	9	11·4	25·0	2	9·1	33·3
ASIA AND THE FAR EAST						
Japan[1]						
Raw fish	7·7	11·3	44·0	3·2	15·0	66·7
Dried fish	8·2	12·1	46·9	0·6	2·8	12·5
OCEANIA						
Cook Islands (Rarotonga)	49·1	46·0	72·4	6·3	5·5	26·1
LATIN AMERICA						
Argentina[2]						
Barranqueras y Puerto Vilelas	0·6	0·7	1·1		—	—
Resistencia	0·7	0·8	1·7	—		—
Peru						
Fresh fish	7·7	15·5	34·1	—	—	—
Dried fish	5·0	10·0	22·1	—	—	—
NEAR EAST AND AFRICA						
Northern Nigeria[3]						
Bida farmers						
Freshwater, dried	4·0	5·3	81·6	0·6	1·4	—
Kontagora farmers						
Freshwater, dried	0·5	0·7	35·7	0·08	0·3	—
Zuru farmers						
Freshwater, dried	0·5	0·6	31·3	0·08	0·3	—
Southern Nigeria[3]						
Warri traders						
Fresh fish	11	13·1	22·0	1·9	2·2	—
Dried fish	15	17·9	30·0	2·4	2·8	—
Canned fish	1	1·2	2·0	0·8	0·9	—
Illu farmers						
Fresh fish	3	7·0	17·6	0·5	1·2	—
Dried fish	9	20·9	52·9	1·4	3·3	—
Soragbemi fishermen						
Fresh fish	28	35·0	41·2	5·0	12·8	—
Dried fish	40	50·0	58·8	6·3	16·2	—

[1] Survey on food consumption of the people in Tokyo living on salaries (March 1944). Intake per adult.

[2] G. per consumption unit per day.

[3] Survey of adults (over 12 years of age).

to what has been said about thiamine, except that fish can make much higher contributions to riboflavin intakes. For example, in the Cook Islands, and in the case of fishermen of Southern Nigeria, up to a third or more of total riboflavin intake is derived from fish. Although deficiencies related to fat intakes have not been reported to be of any significance to public health, it may be of interest to consider here briefly the rôle of fish as suppliers of fat to average diets, in view of the recently increased interest in some aspects of fat in relation to health and disease. Table V will show that, as noted earlier in the case of calcium, the contribution of fish to diets on a national average basis is generally of no importance. However, Table VII will show, again as in the case of calcium, that some sections of the populations within a country might be obtaining a substantial part of fat intake from fish. In Japan, for instance, salaried employees in Tokyo get about 18 per cent of their fat intake, or about 80 per cent of their animal fat intake from fish.

After this review of the rôle of fish in average diets in terms of calories, proteins and other nutrients, it will be now appropriate to consider briefly what all this means in terms of increased fish supplies for better nutrition. No doubt, many efforts have been made in this direction by different people, from various points of view; but a reference to one such effort will be enough to illustrate the need and scope for increasing fish supplies to meet the nutritional needs of the fast increasing populations in the developing regions (5). According to this estimate, the extra quantities of food required to make even a limited nutritional improvement in the average diets of the increasing population of the world, even over a relatively short period of 25 years, would be quite substantial. On a total world basis, it was estimated that an increase of the order of 90 per cent was called for, but that increases of an even higher order would be needed in the case of the under-fed, but fast-increasing, populations in the developing regions: e.g. 120 per cent in Asia and

TABLE VIII

Calcium, thiamine, and riboflavin content of average quantities of fish and products consumed in selected countries in different regions (based on dietary surveys)

	Calcium		**Thiamine**		**Riboflavin**	
Country	mg./cap/day	% of total calcium	mg./cap/day	% of total thiamine	mg./cap/day	% of total riboflavin
EUROPE						
United Kingdom	14	1·4	0·01	0·6	0·03	1·6
NEAR EAST AND AFRICA						
Israel	—	—	—	—	0·02	1
Ivory Coast						
Village	419	56·9	0·02	1·3	0·04	4·8
Camp	389	49·2	0·02	1·0	0·05	4·6
OCEANIA						
Cook Islands (Rarotonga)	51	14·0	0·15	10·0	0·38	38·0
LATIN AMERICA						
Argentina[1]						
Barranqueras y Puerto Vilelas	1·2	0·2	0·002	0·2	0·005	0·3
Resistencia	2·1	0·4	0·002	0·2	0·005	0·3
Peru						
Fresh fish	65·0	23·0	0·005	0·6	0·03	3·8
Dried fish	50·3	17·8	0·005	0·6	0·02	2·5
NEAR EAST AND AFRICA						
Northern Nigeria[2]						
Bida farmers						
Freshwater, dried	160	32·7	—	—	0·02	2·6
Kontagora farmers						
Freshwater, dried	20	5·8	—		0·003	0·4
Zuru farmers						
Freshwater, dried	20	3·4	—	—	0·003	0·3
Southern Nigeria[2]						
Warri traders						
Fresh fish	434	33·3	—	—	0·08	5·8
Dried fish	600	46·1	—	—	0·09	6·6
Canned fish	12	0·9	—	—	0·01	0·7
Illu farmers						
Fresh fish	126	19·0	—	—	0·02	3·1
Dried fish	360	54·2	—	—	0·06	9·2
Soragbemi fishermen						
Fresh fish	1,155	39·9	—	—	0·21	30·9
Dried fish	1,580	54·6	—	—	0·24	35·3

[1] Mg. per consumption unit per day.
[2] Survey of adults (over 12 years of age).

the Far East, and 130 per cent in the Near East. Thus it is clear that there is a vast need and scope for increasing fish supplies, in order to raise the levels of nutrition especially in the developing regions.

In sum, it can be concluded that: (*a*) there is widespread malnutrition in most of the developing regions; (*b*) the levels of nutrition in these regions can be raised mainly by increased consumption of protective foods; (*c*) fish can make substantial contributions in this respect; and (*d*) there is a vast need and scope for increasing fish supplies for this purpose.

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DISCUSSION

In the discussion on Dr. Rao's paper, MR. H. LOREDO (Mexico) reported that the need for protein was a constant problem in Latin America; this, already well known, had been confirmed by a recent ICNND survey. In Mexico, some excellent canned and frozen fish products were manufactured, at a price beyond the reach of the greater part of the population: the rest of the fisheries, unfortunately, were poorly developed, and needed expert assistance.

MR. D. HAMMOND (Ghana): Although there are some very productive fishing regions in Africa, notably around Mali and Lake Victoria in Uganda, social tradition and religious beliefs are very often a severe hindrance to the consumption of fish products for the prevention of protein malnutrition. Dried fish may be an excellent solution to the nutritional problems of Africa, and of Asia and Latin America.

PROF. A. M. LEROY (France): I agree with Dr. Rao that in very many countries there is a lack of protein. In some areas this can be corrected by increasing the production of certain agricultural products: for example, cereal grains and farm animals. Sometimes fish bred in ponds can provide considerable quantities of protein; in some other areas the production of fish flour may help. The elimination of protein deficiency is a difficult problem, and requires regional solutions. No one solution will apply to all areas.

DR. G. VARELA (Spain): One must recognize that food balance sheets for a country give only a general view. There are often wide local variations in nutrition conditions in a single country. Our experience in Spain indicates that an increase in economic level does not usually result in an increase in fish consumption. Local studies are essential, and should concern economic aspects as well as the commercial varieties of available fishery products and their market quality.

DR. G. BORGSTRÖM (U.S.A.): The significance of fish in world nutrition becomes more striking when we consider that the United Kingdom would need to increase their ploughed area by 64 per cent to provide—via dairy cattle—the protein now provided by the sea. Similar figures exist for other countries and areas. To provide sufficient protein for our increasing population, the world's catch of fish needs to be doubled every 10 years.

MR. G. AULISIO (Italy): Although there are large differences in the amount of fish consumed in the different regions of Italy, fish is not usually important in the diet. Good quality fish is too expensive. Second quality fish is a good deal cheaper, but there is too much waste. Improvements in marketing, supply and distribution are needed to lower the cost of fish products.

DR. I. K. ORYEM-OBITA (Uganda): In some countries the following problems must be solved to increase the consumption of fishery products: (1) Distribution—for example, lack of good roads. (2) Taboos against fish: often strongest in areas of greatest supply. (3) Economic problems—how to provide inexpensive fish throughout the year. (4) Local preferences: the types of desirable fishery products vary in different areas. Consumer education by organizations such as UNICEF is the best approach to solving the localized and varied problem areas.

DR. J. M. BENGOA (WHO): Protein deficiency is our most serious problem, and children are much more affected than adults. From 250,000 to 300,000 children could be saved each year, if they could get enough food. Fish should be eaten much earlier in life, so that children from 1 to 4 years old will obtain enough adequate protein. Educational campaigns and increased supplies of fish protein are badly needed.

Dr. K. K. P. N. Rao replied that he was in full agreement with Mr. Hammond and with Prof. Leroy. It was necessary to look at the need for increased fish supplies in the light of the total supply of all protein-containing foods and the protein requirements of the population. To Dr. Varela he answered that, whereas an increase in economic level does not automatically imply an increase in the consumption of fish and other nutritious foods, since other conditions may be required as well, nevertheless an advance in purchasing power is a *conditio sine qua non* for improvements in nutrition.

Are any words required here to show how dire is the outcome of lack of protein which fish can so well provide? On the left is a South American child suffering from malnutrition. Below are shown inhabitants of an Indian village in East Pakistan who are victims of famine. They have been compelled to grub up grass roots to eke out their diet.

FISH PROTEINS IN NUTRITION AND THEIR IMPORTANCE IN THE PREVENTION OF PROTEIN MALNUTRITION

by

JEAN MAYER

Protein malnutrition is the major nutritional problem in the world at present. Fish protein is an excellent protein, which can not only increase the quantity of protein consumed, but can also supplement the quality of the protein. Thus a diet with a moderate amount of mediocre protein can be transformed into a diet with an adequate amount of good quality protein as small amounts of fish are added. Examples of such amino acid supplementation by fish protein will be discussed.

LES PROTEINES DU POISSON DANS LA NUTRITION ET LEUR IMPORTANCE DANS LA PREVENTION DE LA MALNUTRITION PROTEIQUE

La malnutrition protéique est le problème alimentaire majeur du monde actuel. La protéine du poisson est une protéine excellente, qui peut non seulement accroître la quantité de protéines consommée, mais aussi bien améliorer leur qualité. Ainsi, un régime à teneur modérée de protéine médiocre peut être transformé en régime à teneur convenable de protéine de bonne qualité par l'addition de petites quantités de poisson. On exposera des exemples d'une telle supplémentation en amino-acides par la protéine du poisson.

LAS PROTEINAS DEL PESCADO EN LA NUTRICION Y SU IMPORTANCIA EN LA PREVENCION DE LA MALNUTRICION PROTEICA

La malnutrición proteica es el principal problema alimentario del mundo en la actualidad. La del pescado es una proteína excelente que no sólo puede incrementar la cantidad consumida, sino también mejorar su calidad. Así, una alimentación con una cantidad moderada de proteína mediocre puede transformarse en otra con una cantidad adecuada de proteína de buena calidad por adición de pequeñas cantidades de pescado. Se discutirán ejemplos de complementación de aminoácidos con la proteína del pescado.

THE protein-deficiency diseases of young children, kwashiorkor and marasmus, are probably the most common—and most malignant—of all nutritional deficiencies. Even the name of kwashiorkor* is probably unknown to most medical men who studied nutrition before 1950. Although there had been some good descriptions of the disease in the 'thirties, the syndrome was clearly identified only just before the Second World War, and recognized for what it is—one of the most widespread scourges of mankind—only in the late 'forties.

Brief consideration of this syndrome (its cause, treatment and prevention) is probably the best possible introduction to a symposium, the ultimate object of which is to promote better nutrition through an increase in the world-wide consumption of the first-quality protein contained in fish.

Kwashiorkor

The multiplicity of names by which the disease has been termed testifies to its world-wide distribution. Among others the following synonyms have been used: malignant malnutrition (South Africa), which emphasizes the lethal aspects of the disease if untreated; bouffissure d'Annam (Indo-China)—Vietnamese swelling, singling out the edema; fatty liver of Brahmin children (India) which puts the accent on another aspect of the pathology; Sindrome Pluricarencial Infantil (Central America) which illustrates the fact that protein deficiency is usually accompanied by low intakes of the water soluble vitamins. The syndrome has even been observed occasionally in the United States. R. M. Kark has observed one or two cases in Chicago (2) and I believe that sporadic cases have been observed in New Orleans. Kwashiorkor merges with other nutritional syndromes, such as mehlnahrschaden and marasmus, where calories as well as protein are lacking in the diet (3). Kwashiorkor is perhaps best defined as a nutritional syndrome (or syndromes) where a deficiency of good-quality protein appears to be a dominant factor; it is found among many poor populations, especially among young children, in which characteristically there occurs: (*a*) retarded growth and maturation, (*b*) apathy and sometimes also irritability, (*c*) anorexia, (*d*) diarrhea and sometimes vomiting, (*e*) alteration of color and texture of the hair and sometimes of the nails, (*f*) lesions of the skin marking varying degrees of hyperkeratosis, dyspigmentation and desquamation, (*g*) oedema, (*h*) marked fatty infiltration of the liver, (*i*) a heavy mortality in the absence of proper dietary treatment.

Distribution

We have already noted that the various synonyms for the name kwashiorkor (which has become the accepted name, since it was endorsed by the World Health Organization and the Food and Agriculture Organization of the United

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* A Gold Coast term, the meaning of which is yet unclear. Some say it denotes the disease of the second or displaced child and marks its association with weaning; some say the term means red child because of the associated dyspigmentation (1).

Nations) testify to its widespread character. It is found wherever tropical peoples subsist on starchy staple foods without adequate protein supplements. It has been studied particularly thoroughly in Mexico and Central America (4), in South America (5), and in Jamaica (6), in India (7), in Central and South Africa (8, 9, 10); but it is found as well in North Africa, the Near East and in many areas of Asia besides India. Its prevalence within populations can be extremely high. It has been claimed that practically every child in certain African and Central American regions, for example, has or has had some degree of protein malnutrition bordering on kwashiorkor.

Etiology

Lack of proteins, particularly complete proteins, seems to be principally responsible for the constant pathologic changes. These appear to be the result of a deficiency of good-quality protein in general, rather than a deficiency of a single amino acid. The disease is rarely observed during the period of breast feeding, as long as the supply of maternal milk is adequate. It closely follows weaning and transfer of the child to starch gruels, when maternal milk is replaced by low-grade foodstuffs.

Pathology and clinical characteristics

The following signs, symptoms and pathological findings are observed:

(1) Retardation of growth, beginning at the late breast feeding, weaning and post-weaning ages. This character is fundamental, though common to other conditions such as undernutrition due to lack of available calories or to anorexia, marasmus and atrophy. In spite of the serious growth retardation, the infant with kwashiorkor does not always look emaciated or starved. If he has been provided with considerable starch or sugar while he was deprived of protein, his subcutaneous fat may be appreciable; and, particularly if mild oedema is present and dermatosis absent, the infant may give superficially the appearance of good nutrition. (The condition where calories as well as protein are deficient, which is also characterized *inter alia* by emaciation, is termed marasmus and differs somewhat in pathology and prognosis from kwashiorkor.)

(2) Oedema. Serum albumin is generally reduced in kwashiorkor, and is almost universally reduced to a marked degree in oedematous kwashiorkor. Relative hyperglobulinemia is often present, whether as a compensatory reaction, as a result of parasitic infestation or secondary to liver damage.

(3) Liver. The liver is usually not palpable, but is universally found to be extremely infiltrated with fat, frequently to such an extent that the normal lobulation is hardly recognizable.

(4) Dyspigmentation and dermatoses. There may be both a reduction of quantity of hair, and skin-pigment and qualitative alteration. This must be distinguished from hypopigmentation due to admixture with people of lighter color in inborn mutations ("half albinos"). Skin dyspigmentation due to kwashiorkor can be patchy or diffuse and in some cases may cover the entire body. Hyperpigmentation is also frequently observed.

Dermatoses properly speaking do not appear to be the same in various regions of the world, and therefore probably have several different origins. A most common form is an eruption of sharply defined black varnished patches on areas exposed to irritation (diaper area, buttocks, back, etc.), and not confined to areas exposed to sunlight (hand and face), thus permitting differentiation from pellagra. The hyperpigmented areas may become dry, cracked, scaled and peel. In extreme cases they may blister and resemble second-degree burns.

Vascular fragility, ischemia and necrotic lesions are also seen in extreme cases in many areas of the world.

(5) Gastrointestinal disorders, pancreas and duodenal enzymes. Mucosal lesions and atrophy, diarrhea and deficient intake may be all part of a vicious circle. Pancreatic fibrosis is observed, but is by no means a constant finding. Drastically reduced lipase, trypsin and amylase may be a result of the atrophy of the pancreas and duodenal mucosa.

(6) Psychic changes. Children with kwashiorkor are usually apathetic and anorexic. They appear extremely miserable, and may be irritable, though they rarely cry.

(7) Mortality in untreated cases. The mortality in the untreated syndrome is very high. Recent studies suggest that the heavy mortality is associated with irreversible biochemical changes. In the absence of proper treatment, the mortality is never less than 30 per cent and in some areas goes up to 100 per cent.

Treatment

Well-planned treatment is based on our understanding of the primary factor in the etiology; i.e. primary deficiency of good-quality proteins often associated with vitamin deficiency, diarrhea and parasites. Other factors taken into account are the degree of severity of the case, the nature and extent of dehydration and electrolyte imbalance, and the presence and nature of intestinal parasitosis and other infections.

The main treatment is dietary. In children over 3 years old, when the general condition is fair, a complete and balanced diet is given from the outset, adjusted to the age of the child but consisting largely of skim milk and animal protein (2 g. per kg. of body weight per day at the start, building up to 5–7 g. as soon as possible (1 week to 10 days usually)), fresh vegetables and bananas. Some fat can be included as a source of calories after the first few days of treatment. In younger children, when the digestive troubles are slight, milk in the dilution of two parts of fresh milk to one part of water (or rice water) may be given. In more severe cases increasing amounts of skim milk, diluted, should be administered, exercising due caution in the process. Skim milk is sometimes acidified, as well as diluted to facilitate digestion by producing smaller coagulation clots. Treatment may start with 2–3 g. of protein and 60 calories per kg. of body weight. Concentration is progressively increased, so that as soon as possible 6–7 g. of protein per kg. of body weight be reached. Within 2 weeks, the caloric intake should be built up to 100–120 calories per kg. of body weight.

If anorexia is intense at the beginning, a nasal tube is used. Loss of weight indicates the disappearance of edema, and indicates the need for a substantial change to a more varied diet. Clinical experience has shown that the administration of the vitamin B complex in large doses is not only useless but sometimes makes the condition worse. Vitamins C and A, in physiological doses (the water emulsified form of synthetic vitamin A is preferable), are often given in the early treatment, as these are the two vitamins lacking in the diet based on skim milk. Results of use of lipotopic agents have been poor. Vitamin B_{12} and folic acid have been used when anemia is present and the diet poor in these nutrients. Ferrous sulphate (300–600 mg. orally per day) may be introduced in the course of the first or second week of treatment. Penicillin may be given from the outset as a routine precaution against possible infection, which in children with kwashiorkor may not manifest itself by fever or by elevated white cell count. Children do better if they receive personal attention and affection throughout treatment.

The following emergency treatments have given good results in severe cases: (*a*) in marked dehydration, following diarrhea and vomiting (with or without oedema), appropriate intravenous electrolyte solutions; (*b*) in the presence of shock or extreme anemia, blood transfusions. The treatment of specific diseases such as malaria begins by using the less toxic drugs. The treatment of intestinal parasitosis is not undertaken until the child has recovered sufficiently to start treatment without danger.

Prognosis in treated cases

The short-term prognosis of mild cases given full treatment is good. The frequency of multiple episodes is high when home conditions are unfavorable. Recurrences take place, not only in children taken home by the parents before the cure is complete, but also (though less commonly) in children who leave the hospital "clinically cured". Relapse usually occurs 3–6 months after the child has left the hospital. The clinical state during relapse is usually similar, and often more serious than at first admission. Mortality rate in such cases continues high.

The prognosis of apparently successfully treated cases over a longer or life-span period is not known. It is unlikely, from their world distribution, that cirrhosis and primary carcinoma of the liver on the one hand, and kwashiorkor on the other, are related in any direct cause-and-effect manner. Adult cirrhosis may well result from the effects of continued protein deficiency and parasitosis, infection, and toxic factors on liver already damaged in childhood by kwashiorkor. A similar situation probably exists in respect to primary carcinoma of the liver.

Prevention

Proper prevention is based on:

(1) Increasing the supply of animal proteins, which entails development in particular of milk-producing livestock (sc. cattle, sheep and goats), of poultry (particularly egg-laying hens), and of developing proper veterinary and processing facilities. The expansion of fisheries, of fish farming and of fish processing facilities, offers considerable promise; in many cases may be the most practicable way of increasing animal proteins. After all, fish is one type of edible animal which is not obtained at the expense of feed which could have been utilized directly for human nutrition.

(2) Developing proper mixtures of adequate vegetable protein, in particular by increasing availability of pulses, nuts and green vegetables.

(3) Eliminating the "hungry months" during which incidence of kwashiorkor increases, by developing cash crops and other additional sources of income.

(4) Supplementary feeding programs directed towards infants and young children, with emphasis on foods providing adequate amounts of good-quality protein. Here again fish, fish meal and fish flour can play an essential rôle.

(5) Education: with the best intentions, young mothers in poor tropical countries commit many grave faults in the nutrition of their children. When education programs in proper nutrition are put into operation, it is usually found that changes in traditional patterns of infant and small child feeding can be introduced fairly rapidly. Maternity and child health centers have had considerable influence on nutrition habits. Family dietary habits can also be influenced through schools, though in underdeveloped areas girls usually constitute a minority in school attendance. Such education programs, whether they take place within or outside schools, should emphasize the value of fish in the nutrition of young children and of pregnant and lactating women. All too often these particular groups do not consume fish, because of misguided ideas about fish digestibility even though there are no religious taboos against fish in the population of which they are members.

(6) Social welfare: in poor areas there are usually substantial numbers of small children who suffer from plain neglect. This situation can only be remedied through the work of strong social agencies, which in turn have to be educated as regards nutritional requirements of this age group.

Protein requirements

Consideration of protein deficiencies, such as kwashiorkor, quite naturally leads us to the examination of the problem of protein requirement. There are at least two kinds of such requirements: one concerning the total *quantity* of needed protein, the other concerning the *quality* of such protein (that is essentially the amino acid composition of the proteins). Requirement for total

TABLE I

Food and Nutrition Board, National Research Council recommended daily dietary allowances,[1] revised 1958

Designed for the maintenance of good nutrition of healthy persons in the U.S.A.
(Allowances are intended for persons normally active in a temporate climate)

	Age Years	*Weight kg.*	*(lb.)*	*Height cm.*	*(in.)*	*Calories*	*Protein g.*	*Calcium g.*	*Iron mg.*	*Vitamin A I.U.*	*Thiam. mg.*	*Ribo. mg.*	*Niacin[2] mg. equiv.*	*Asc. Acid mg.*	*Vitamin D I.U.*
Men	25	70	(154)	175	(69)	3,200[3]	70	0·8	10	5,000	1·6	1·8	21	75	
	45	70	(154)	175	(69)	3,000	70	0·8	10	5,000	1·5	1·8	20	75	
	65	70	(154)	175	(69)	2,550	70	0·8	10	5,000	1·3	1·8	18	75	
Women	25	58	(128)	163	(64)	2,300	58	0·8	12	5,000	1·2	1·5	17	70	
	45	58	(128)	163	(64)	2,200	58	0·8	12	5,000	1·1	1·5	17	70	
	65	58	(128)	163	(64)	1,800	58	0·8	12	5,000	1·0	1·5	17	70	
	Pregnant (second half)					+300	+20	1·5	15	6,000	1·3	2·0	+3	100	400
	Lactating (850 ml. daily)					+1,000	+40	2·0	15	8,000	1·7	2·5	+2	150	400
	Months														
Infants	0–1[4]						See footnote[4]								
	2–6	6	(13)	60	(24)	kg. × 120		0·6	5	1,500	0·4	0·5	6	30	400
	7–12	9	(20)	70	(28)	kg. × 100		0·8	7	1,500	0·5	0·8	7	30	400
	Years														
Children	1–3	12	(27)	87	(34)	1,300	40	1·0	7	2,000	0·7	1·0	8	35	400
	4–6	18	(40)	109	(43)	1,700	50	1·0	8	2,500	0·9	1·3	11	50	400
	7–9	27	(60)	129	(51)	2,100	60	1·0	10	3,500	1·1	1·5	14	60	400
	10–12	36	(79)	144	(57)	2,500	70	1·2	12	4,500	1·3	1·8	17	75	400
Boys	13–15	49	(108)	163	(64)	3,100	85	1·4	15	5,000	1·6	2·1	21	90	400
	16–19	63	(139)	175	(69)	3,600	100	1·4	15	5,000	1·8	2·5	25	100	400
Girls	13–15	49	(108)	160	(63)	2,600	80	1·3	15	5,000	1·3	2·0	17	80	400
	16–19	54	(120)	162	(64)	2,400	75	1·3	15	5,000	1·2	1·9	16	80	400

[1] The allowance levels are intended to cover individual variations among most normal persons as they live in the United States under usual environmental stresses. The recommended allowances can be attained with a variety of common foods, providing other nutrients for which human requirements have been less well defined. See text for more detailed discussion of allowances and of nutrients not tabulated.

[2] Niacin equivalents include dietary sources of the preformed vitamin and the precursor, tryptophan. 60 mg. tryptophan equals 1 mg. niacin.

[3] Calorie allowances apply to individuals usually engaged in moderate physical activity. For office workers or others in sedentary occupations they are excessive. Adjustments must be made for variations in body size, age, physical activity and environmental temperature.

[4] See text for discussion of infant allowances. The Board recognizes that human milk is the natural food for infants and feels that breast feeding is the best and desired procedure for meeting nutrient requirements in the first months of life. No allowances are stated for the first months of life. Breast feeding is particularly indicated in the first months when infants show handicaps in homeostasis due to different rates of maturation of digestive, excretory and endocrine functions. Recommendations as listed pertain to nutrient intake as afforded by cow's milk formulas and supplementary foods given the infant when breast feeding is terminated. Allowances are not given for protein during infancy.

protein has been studied since the second half of the nineteenth century. Innumerable experiments have established, for example, the fact that there is an irreducible need for something of the order of half a gram of good-quality protein per kilogram in adult men and women (non-pregnant or lactating); the requirements are somewhat larger if the protein is not of the best quality. (If the protein is very poor, as we shall see later, no amount of protein would actually fulfil the requirement.) From a practical standpoint, the best-known table of requirements of total protein of mixed origin (animal and vegetable) is contained in the recommended dietary allowances of the Food and Nutrition Board of the National Research Council of the United States (Table I). A more rigorous set of values, expressed in terms of absolute minimum of first-rate protein without any margin of safety, is given in the protein requirement committee report of the FAO (13). The second type of requirement concerning protein is that for a certain quality of protein . . . more specifically, as will be seen, for a certain balance of "essential" amino acids.

Requirements for amino acids are thus quite different from requirements for vitamins and minerals. These are essentially *minimum* amounts which have to be provided to avoid disease or to insure optimum performance, no matter what the rest of the diet may include. Granted, there is some relationship between these minimums and diet composition. For example, a high carbohydrate diet increases the requirement for thiamine; a high protein diet decreases the requirement for nicotinic acid; the availability of a large amount of antioxidants (e.g. vitamin E) in the diet spares vitamin A, etc. Still, all in all, minimum requirements for such nutrients can be stated in tables of recommended dietary allowances (11) in terms of so many mg. or g. per day, without having detailed reference to dietary composition.

The situation is quite different as regards amino acids. While early work (12) formulated the daily requirements of amino acid in terms of a minimum (in mg. per day),* it has come to be realized (13) that such an approach was erroneous. When no less than the "minimum" or the

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* Sometimes multiplied by two to provide for a "margin of safety" and to yield an "optimum" daily requirement.

"optimum" of a given amino acid has been administered, it is still possible to throw the subject into negative nitrogen balance by administering relative excesses of other essential amino acids. In other words, when dealing with amino acid requirements we are dealing with need for a *pattern* of essential amino acids. (For that matter the pattern of non-essential amino acids may exert some influence as well.) There is thus no contradiction between the statement that the protein intake of most Americans is much higher than requirements and the statement that the problem of amino acid requirements may be of clinical importance even in the United States.

The concept of essential amino acids

This theory of the indispensability of amino acids (i.e. that there are amino acids which the body cannot synthesize, and which have therefore to be provided by the diet) goes back to the demonstration by Willcock and Hopkins in 1906 that rats could not grow on a diet devoid of tryptophan. Two other pioneers, Osborn and Mendel, working at Yale, demonstrated that the amino acid composition of proteins determined their "biological value", i.e. their value as a source of protein for growth of experimental animals. It is, however, to Rose (12) that we are indebted for a clear and detailed knowledge of indispensable amino acids. He perfected a technique of substituting purified amino acids for protein in the diets of experimental animals, and of testing, by omitting one amino acid at a time, whether growth stopped and maintenance became impossible. If growth stopped, the amino acid was essential for growth. If maintenance became impossible, the amino acid was indispensible for maintenance of the adult state as well. The work was held up for a number of years by the finding that no known mixture of synthetic amino acid could replace a casein hydrolysate for the growth of rats. Finally in 1934, this "baffling situation" was cleared up by the isolation in pure form of a missing amino acid, threonine (14). Considerable work over the years led to the demonstration that the following amino acids could be classified as essential and non-essential for the rat (15).

Essential amino acids in man

Rose tackled the problem of amino acid requirements in adult man (12, 16, 17) by using mixtures of pure acids as the source of nitrogen in his diets. As in his animal studies, one or more of the amino acids were omitted. The maintenance of nitrogen balance was used as the criterion of essentiality of amino acids. It was thus shown that valine, methionine, threonine, leucine, isoleucine, phenylalanine, tryptophan and lysine are essential. The removal of histidine and of arginine did not lead to negative nitrogen balance (Table II). It thus appears that these two amino acids are not essential in man. The problem of elucidating the nature and the daily need of essential amino acids was extended to infants by Holt and his associates (18), and to women by a number of groups of investigators (19, 20, 21, 22). A summary of the results of these investigators is presented in Table III. In spite of the existence of a considerable body of information thus available, the following limitations to our knowledge must be recognized:

TABLE II

Classification of the amino acids with respect to growth effect in rats

Essential	*Non-essential*
Lysine	Glycine
Tryptophan	Alanine
Histidine	Serine
Phenylalanine	Cystine[2]
Leucine	Tyrosine[3]
Isoleucine	Aspartic acid
Threonine	Glutamic acid
Methionine	Proline
Valine	Hydroxyproline
Arginine[1]	Citrulline

[1] Arginine can be synthesized by rats, but not at a rate sufficient to fulfil the requirements for maximum growth. It is thus really in an intermediary status, and can be classified either as essential or as non-essential, depending on definition.

[2] Cystine can replace about one-sixth of the methionine. It has no growth effect in the absence of methionine.

[3] Tyrosine can replace about one-half the phenylalanine. It has no growth effect in the absence of phenylalanine.

TABLE III

Average minimal requirements for essential amino acids as determined by different workers (13), human data

					Sulfur-containing acids					
	Isoleucine	*Leucine*	*Lysine*	*Phenylalanine*	*Methionine*	*Cystine*	*Total*	*Threonine*	*Tryptophan*	*Valine*
	Average minimal needs, milligrams per kilogram body weight									
Men	10·4	9·9	8·8	4·3[2]	1·5	11·6	13·1	6·5	2·9	8·8
				13·3[3]	13·2	0	13·2			
Women	5·2	7·1	3·3	3·1[4]	4·7	0·5	5·2	3·5	2·1	9·2
					3·8	(2·2)	6·0			
					3·4	3·4	6·8			
					3·0	(4·2)	7·2			
Infants	90	—	90	88[1]	85	0	85	60	30	85
					65	pres.	– –			

[1] Tyrosine present.

[2] 15·9 mg. tyrosine per kilogram; ratio of tyrosine to tryptophan equals 5·5.

[3] No tyrosine.

[4] 15·6 mg. tyrosine per kilogram; ratio of tyrosine to tryptophan equals 7·4.

(1) The number of subjects used in each experiment, whether adult men or women or infants, was of necessity small. We have thus only limited knowledge of the extent of individual variability in amino acid requirements in man. Data on amino acid excretion suggest that this variability may be appreciable.

(2) We have no experimental data on requirements between infancy and adulthood. In particular, we do not know whether the prepuberty growth spurt is accompanied by any qualitative changes in amino acid requirements; an unlikely, but by no means impossible, eventuality.

(3) No explanation is available for the fact that in determining of requirements for essential amino acids where these were fed as the pure substances, it was necessary to provide calories far in excess of normal requirements to obtain nitrogen balance. This was particularly true in Rose's experiments in adult men.

(4) The interrelationship between amino acids is such that requirements for one are influenced by intakes of others. The "minimum" values obtained when one amino acid is dropped from the mixture fed to the subject, and its intake gradually built up until nitrogen balance is reached, are of necessity a function of the intake of the other essential amino acids. For example, while the view had been generally held that imbalance among amino acids was unlikely to occur when only natural foods were ingested, it has been recently shown (23) that the amount of leucine in corn may be large enough to increase the requirements for isoleucine.

(5) The human requirements for amino acids are obviously influenced by a number of additional factors such as the caloric value of the diet, the sparing of protein by carbohydrate and fat, and the timing of the intake of foods containing proteins.

(6) The experiments referred to above were carried out under experimental conditions designed to spare the essential amino acids from the need to contribute to the synthesis of the unessential amino acids. Unless the latter are in ample supply, the need for essential amino acids will be increased. For example, under experimental conditions where low levels of protein intake are obtained from milk, certain non-essential forms of nitrogen are limiting and the need to synthesize these creates a demand beyond the minimal requirements (18). Generally speaking, in man as in experimental animals, the pattern as well as the amount of non-essential amino acids may be of importance.

(7) Finally, in man as well as in experimental animals, the ability of the non-essential amino acids (cystine and tyrosine) to spare much of the required methionine and phenylalanine respectively is of relevance in determining requirements for these two essential amino acids.

The FAO provisional pattern of human amino acid requirements

The international committee, which met in 1957 in Rome under the sponsorship of the Food and Agriculture Organization to draw practical recommendations concerning protein requirements, was struck by the fact that, while the amounts of essential amino acids found by various investigators to be needed by men, women, and infants varied considerably (Table III) the pattern of requirements for each amino acid in relation to the others was much more constant. In particular, it noted that, if the amount of (for example) tryptophan found to be required in the experiments cited above was taken as unity and the proportion of other amino acids given in Table III was recalculated to give the pattern given in Table IV, the variability of amino acids requirements is considerably reduced. That this reduction in variability was not simply an artifact of presentation is confirmed by the repeated demonstrations of interrelationship between requirements for the various amino acids. Another indication of the value of this approach is the remarkable similarity between patterns of human requirements and the patterns of essential amino acids in the proteins of "high biological value" (eggs, fish, meat, milk, etc.); i.e.

TABLE IV

Pattern of essential amino acids, when requirements are expressed in relation to tryptophan (13)

					Sulfur-containing acids					
	Isoleucine	*Leucine*	*Lysine*	*Phenylalanine*	*Methionine*	*Cystine*	*Total*	*Threonine*	*Tryptophan*	*Valine*
Men	3·6	3·4	3·0	(1·5[2]	0·5	4·0	4·5)	2·2	1·0	3·0
				(4·6[3]	4·6	0	4·6)			
Women	2·5	3·3	1·6	1·5[4]	(2·2	0·3	2·5)	1·7	1·0	4·4
					(1·8	(1·0)	2·8)			
					(1·6	1·7	3·3)			
					(1·4	(2·0)	3·4)			
Infants	3·0	—	3·0[1]	3·0[1]	(2·8	0	2·8)	2·0	1·0	2·8
Provisional pattern	3·0	3·4	3·0	2·0[5]	1·6	1·4	3·0	2·0	1·0	3·0

[1] Tyrosine present.
[2] 15·9 mg. tyrosine per kilogram; ratio of tyrosine to tryptophan equals 5·5.
[3] No tyrosine.
[4] 15·6 mg. tyrosine per kilogram; ratio of tyrosine to tryptophan equals 7·4.
[5] Assumes about 5·0 mg. per kilogram of tyrosine; ratio of tyrosine to tryptophan equals about 2·0.

those proteins found to be the most efficient in fulfilling human requirements.

It thus appeared reasonable to the FAO committee to express amino acid requirements in terms of an ideal proportion of essential amino acids, using their collective judgment to evolve such a provisional pattern on the basis of results of determinations of amino acid requirements in man. Table V describes this provisional pattern in terms of grams of the essential amino acids per 100 g. of protein and of milligrams of essential amino acid per gram of nitrogen. In both cases a balance between essential and non-essential amino acids in the total protein has been arrived at by determining arbitrarily that the proportion of tryptophan is the same for the protein corresponding to the provisional pattern and for cow's milk. Table V gives, besides the proportions of essential amino acids in the provisional pattern and in cow's milk, the proportions in human milk and egg, two other superior sources of protein. It also gives for purposes of comparison a composite analysis of the amino acids of fish meal. It will be seen that this, too, is a source of first-rate protein.

TABLE V

Essential amino acids in provisional pattern and milk and egg and fish proteins (13)

	Provisional pattern	*Cow's milk*	*Human milk*	*Egg*	*Fish Meal Protein*
	Grams amino acid per 100 g. protein				
Isoleucine . .	4·2	6·4	6·4	6·8	6·8
Leucine . . .	4·8	9·9	8·9	9·0	9·3
Lysine . . .	4·2	7·8	6·3	6·3	9·0
Phenylalanine. .	2·8	4·9	4·6	6·0	3·5
Tyrosine . .	2·8	5·1	5·5	4·4	5·0
Sulfur-containing:					
Total . . .	4·2	3·3	4·3	5·4	6·3
Methionine .	2·2	2·4	2·2	3·1	5·3
Threonine . .	2·8	4·6	4·6	5·0	—[1]
Tryptophan . .	1·4	1·4	1·6	1·7	1·0[2]
Valine . . .	4·2	6·9	6·6	7·4	5·9

[1] Figure not available.
[2] Value uncertain and probably higher.

Practical applications of these concepts

The provisional amino acid pattern is being used by FAO and other international agencies concerned with the feeding of populations as a guide to the supplementation of protein-poor diets. For example, Table VI prepared by the Nutrition Division of FAO (24) shows how the pattern can be used to realize supplementation of diets consisting mainly of wheat, rice, maize by relatively small amounts of fish meal.

The United States Department of Agriculture has compiled tables giving the amino acid content of foods (25). These were established for 316 items and expressed in amino acids per gram of total nitrogen in edible proteins of foods, and amino acid content per 100 g. of edible protein. The amino acids determined are: tryptophan, threonine, isoleucine, leucine, lysine, methionine, cystine, phenylalanine, tyrosine, valine, arginine, histidine, alanine, aspartic acid, glutamic acid, glycine, proline and serine. The maximum, minimum and average content is given for the values found in samples of each item.

The Commonwealth Bureau of Animal Nutrition (Great Britain) has also published a compilation of amino acid contents of foods and feedingstuff (26). The availability of such tables makes it possible to calculate the "protein score" of a given foodstuff or diet. This protein score is the percentage of relative requirement furnished by the food material for the amino acid found to be most deficient in that particular food or diet when compared with the provisional pattern. In other words, the protein score measures the extent to which a food or food combination supplies the limiting amino acid as compared to the provisional pattern. Precise concordance cannot be expected for each food owing to the inaccuracy of our knowledge of amino acids requirements in man, and of the amino acid composition of foods, and to the partial unavailability of amino acids in certain poorly digestible foods. Results are good enough to suggest as a rough guide that foods and food mixtures with a protein score (or a biological value) of 60 or less are unsatisfactory for growth and maintenance, and that a protein score of 70 or more is required for growth.

Conclusion: The importance of fish in the prevention of protein deficiency

I hope that by now the case has been clearly made that fish protein not only constitutes a very welcome addition to the total amount of protein in deficient diets, but that it also permits the supplementation of dietary protein of bad quality. In other words, it not only increases total protein, but its addition makes a poor or mediocre protein mixture a supplemented protein of adequate quality.

There are very few areas of the world where judicious addition of fish protein is not only nutritionally feasible, but also entirely acceptable. Granted, there are some areas such as certain parts of India (or at least certain population groups) where there are taboos against almost all animal proteins including fish. Such areas or population groups, however, are exceptional. My experience in India and in Africa has been that the majority of the populations is already using fish, and will use it whenever available. And whilst in many cases it remains a problem that those population groups which most need the fish protein are forbidden by custom—not by religious taboos—from consuming it, it is usually relatively easy to change such preconceptions by education. This has already been done successfully in many parts of the world. The fish consumption campaign conducted by FAO in Morocco is an example in point.

I should like to make a special plea before concluding this paper. It has been my personal observation that in some areas there has been excessive concern with the

TABLE VI

Effect of fish meal supplementation on diets consisting mainly of wheat, rice or maize

Foods		*Calories*	*Protein*	*Arginine*	*Histidine*	*Isoleucine*	*Leucine*	*Lysine*	*Methionine*	*Phenylalanine*	*Threonine*	*Valine*	*Tryptophan*
		No.	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*
Wheat, whole soft	100 g.	333	10·5	0·48	0·24	0·45	0·79	0·30	0·28	0·57	0·37	0·48	0·14
Rice, white	100 g.	360	6·7	0·51	0·12	0·37	0·58	0·23	(0·2)	0·35	0·27	0·44	0·09
Maize, whole	100 g.	356	9·5	0·46	0·24	0·61	1·42	0·22	0·29	0·48	0·35	0·50	0·06
Fish meal, example	100 g.	365	75·0	6·07	1·95	4·42	6·82	7·12	1·95	3·30	3·82	4·80	0·62
Wheat supplementation													
Requirements, child 9 kg.		990	31·5	1·13	0·57	0·81	3·82	1·53	0·77	1·52	0·78	1·45	0·27
Wheat, whole soft 250 g.		832	26·2	1·20	0·60	1·12	1·98	0·75	0·70	1·42	0·92	1·20	0·35
Non-covered needs		158	5·3	—	—	—	1·84	0·78	0·07	0·10	—	0·25	—
Fish meal supplement (P)	[1]7 g.	26	5·3	0·42	0·14	0·31	0·48	0·50	0·14	0·23	0·27	0·34	0·04
Fish meal supplement (P + A)	[2]11 g.	40	8·3	0·67	0·22	0·48	0·75	0·78	0·22	0·36	0·42	0·53	0·07
Rice supplementation													
Requirements, child 9 kg.		990	31·5	1·13	0·57	0·81	3·82	1·53	0·77	1·52	0·78	1·45	0·27
Rice, white	250 g.	900	16·8	1·28	0·30	0·92	1·45	0·58	(0·5)	0·88	0·68	1·10	0·22
Non-covered needs		90	14·7	—	0·27	—	2·37	0·95	0·3	0·64	0·10	0·35	0·05
Fish meal supplement (P + A)	[2]20 g.	73	15·0	1·21	0·39	0·88	1·36	1·42	0·39	0·66	0·76	0·96	0·12
Maize supplementation													
Requirements, child 9 kg.		990	31·5	1·13	0·57	0·81	3·82	1·53	0·77	1·52	0·78	1·45	0·27
Maize, whole	250 g.	890	23·8	1·15	0·60	1·52	3·55	0·55	0·72	1·20	0·88	1·25	0·15
Non-covered needs		100	7·7	—	—	—	0·27	0·98	0·05	0·32	—	0·20	0·12
Fish meal supplement (P)	[1]10 g.	36	7·5	0·61	0·20	0·44	0·68	0·71	0·20	0·33	0·38	0·48	0·06
Fish meal supplement (P + A)	[2]20 g.	72	15·0	1·21	0·39	0·88	1·36	1·42	0·39	0·66	0·76	0·96	0·12

[1] (P) – supplement necessary to cover deficit in total protein.

[2] (P + A) – supplement necessary to cover deficit in total protein and deficits in amino-acids not already covered by (P) (leucine excepted).

Note to Table VI

More specifically this table illustrates the supplementary effect of the essential amino acids of edible fish meal when added to diets consisting mainly of cereals, in the case of a 9 10 months old infant weighing about 9 kg. who, for one reason or another, no longer receives mother's milk. (It is realized that under usual conditions in underdeveloped areas, many children of this age will still receive some milk from the breast, but this is often a decreasing and by then unreliable amount).

It will be observed that, theoretically, a fish meal supplement of 7 g. per day will supply the balance of total protein required, and also a few essential amino acids, not covered by a daily intake of 250 g. wheat. The addition of a further 4 g. fish meal will meet the total requirement for lysine, but not that for leucine.

In the case of maize, the leucine requirement is covered by the 10 g. fish meal added to meet the total protein deficit, but a greater amount of fish meal is needed to meet the requirements for lysine and tryptophan. With rice, which has a relatively low protein content, a greater supplement of fish meal is necessary to cover the protein and amino acid requirements. Here, as in the case of wheat, the leucine requirement is not fulfilled. With respect to these leucine deficits, it may be noted that if, instead of fish meal, dried skimmed milk were added to the wheat and rice "diets" (on a comparable protein basis), the leucine requirement would remain uncovered.

Sources of information used in Table VI

Calorie requirements: *Calorie Requirements*, FAO, 1950.
Protein requirements: *Recommended Dietary Allowances*, N.R.C., U.S.A., 1953.
Amino acid requirements: A. A. Albanese. *Protein and Amino-acid Requirements of Mammals*, 1950.
Caloric and protein contents: *FAO Food Composition Tables for International Use*, 1949 and 1954.
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preparation of an odorless, and for that matter tasteless, fish flour. West African populations, for example, like fish, and are used to consuming dried fish with a strong smell and taste. There is very little point in trying to provide them with a tasteless, odorless fish flour, which they often do not know how to market, when the same nutritional results could be obtained more cheaply by providing them with dried fish. Granted, if fish flour is required for special use—such as fortification of bread flour or manufacture of infant food—there is justification for it. In most areas, however, it seems to me that the production of fish flour has been a waste of time, and it would have been more useful to simply teach mothers to use dried fish to make an acceptable food for small children.

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Arkansas, U.S.A. (see next page), may be rearing pond fish profitably and satisfactorily but it is only copying a well established practice from the Far East, where the village fish pond provides much satisfactory food. These ponds are being extensively encouraged and developed by FAO throughout Asia, Indonesia and Africa as well as in Mexico and South America.

THE NUTRITIVE VALUE OF BUFFALO FISH AND OTHER ARKANSAS POND-REARED FISH

by

M. C. KIK

Little is known about the nutritive value of buffalo fish and other fish species cultivated in ponds and rice fields in Arkansas.

This paper reports results of growth and metabolism experiments with young rats fed on diets composed of buffalo fish and other fish species as the only source of protein. It includes a study of the effect of replacing cereal proteins with those of buffalo fish; 1, 3, and 5 per cent of those solids *replaced* equivalent amounts of proteins in cereal grain rations, in which the protein level remained the same. Another series of experiments was made on the effect of *adding* small amounts of those solids which increased the protein level slightly. The amino acid content was determined by the proteins of these fish species. The cereal grains included whole and milled rice, whole and milled rice flour, whole and milled yellow corn, milled white corn, whole barley and whole and milled wheat.

The animals were 28–32 days old; *ad libitum* and paired feeding experiments of 70 days' duration were used. Each group consisted of 6 males and 6 females; they were weighed weekly and daily feed consumption was recorded. From these data efficiency ratios (PER) were calculated, expressed as gain in body weight per g. of protein intake. Large quantities were obtained of big mouth buffalo, sc. *Ictiobus cyprinellus* (Valenciennes); large mouth black bass, sc. *Micropterus salmoides* (Lacepede); red cat fish, *Ictalurus nebulosus* (Le Sueur); and gizzard shad, *Dorosoma cepedianum* (Le Sueur). They were pond-reared, or reared in irrigated rice fields. The fish material was frozen, dried at room temperature with the aid of fans, and the fat extracted with petroleum ether. The protein content of the fat-free buffalo fish was 79·1 per cent, of bass 73·5 per cent, of red cat fish 76·6 per cent, of gizzard shad 59·6 per cent.

Table I gives results of growth experiments of rats fed on buffalo fish at a 9 per cent protein level. The value obtained for this species compared favourably with those obtained for whole egg, whole milk, non-fat dry milk solids and lactalbumin, all of which are considered to contain good protein.

Results of the supplementary value experiments revealed that small amounts of the proteins of fish had a supplementary effect for the proteins of milled and whole grains. Table II shows results for milled and whole rice.

The fish-supplemented cereal grains were more efficiently utilized, and promoted better growth, as a result of the smaller losses of nitrogen in metabolism. Table III shows results for milled and whole rice.

The proteins of these fish species are very high in the essential amino acids : lysine, threonine, tryptophan and methionine.

This might explain their supplementary effect on the proteins of whole and milled cereal grains, which are noted for the low content of lysine and tryptophan in corn, and of lysine in other grains. It is concluded that these fish species have a high nutritive value and are good supplements for whole and milled cereal grains.

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LA VALEUR NUTRITIVE DU "BUFFALO FISH" ET AUTRES POISSONS D'ETANGS DE L'ARKANSAS

On sait peu de la valeur nutritive du "buffalo fish" et des autres espèces de poisson élevées dans les marais et les rizières de l'Arkansas.

Dans cet article on expose les résultats d'élevage et d'expériences de métabolisme avec de jeunes rats nourris de régimes composés de "buffalo fish" et d'autres espèces de poissons comme source unique de protéines. On y a inclus une étude sur les effets du remplacement des protéines de céréales par celles du "buffalo fish"; 1 %, 3 % et 5 % de ces solides *remplaçaient* des montants équivalents de protéines dans des rations de céréales, où le taux de protéines restait le même. On a effectué d'autres séries d'expériences sur les effets obtenus en *ajoutant* de petites quantités de ces solides qui élevaient légèrement le taux de protéines. On a déterminé la teneur en amino-acides sur les protéines de ces espèces de poissons. Les céréales comprenaient du riz entier et décortiqué, de la farine de riz entier et décortiqué, du maïs jaune entier et décortiqué, du maïs blanc entier et décortiqué, de l'orge entière et du blé entier et décortiqué.

Les animaux étaient âgés de 28 à 32 jours; des expériences d'alimentation *ad libitum* et appariées se sont poursuivies durant 70 jours. Chaque groupe était composé de 6 mâles et de 6 femelles. On a calculé depuis les données obtenues les rapports d'efficacité protéiques, exprimés en gain de poids par gramme de protéine absorbée.

On a réuni une grande quantité de "big mouth buffalo" (*Ictiobus cyprinellus*, Valenciennes), de "large mouth black bass" (*Micropterus salmoides*, Lacépède), de "red cat fish" (*Ictalurus nebulosus*, Le Sueur) et de "gizzard shad" (*Dorosoma cepedianum*, Le Sueur), qui étaient élevés en étangs et en rizières irriguées. Cet ensemble de poissons a été congelé, séché à la température de laboratoire à l'aide de ventilateurs, et dégraissé à l'éther de pétrole. La teneur en protéine du "buffalo fish" sans graisse était de 79, 1 %; celle de la "bass" de 73,5 %; celle du "red cat fish" de 76,6 % et celle du "gizzard shad" de 59,6 %.

Le tableau I donne les résultats des expériences de croissance sur des rats nourris aux "buffalo fishes" à un taux de 9 % de protéines. La valeur obtenue pour ces espèces se laisse favorablement comparer avec celles obtenues pour l'oeuf entier, le lait entier, les solides et la lactalbumine du lait sec sans graisse, produits considérés tous comme riches en bonnes protéines.

Les résultats des expériences sur la valeur de supplémentation a révélé que de petites quantités de protéines de poisson ajoutent un effet supplémentaire aux protéines des céréales entières et décortiquées. Le tableau II montre les résultats obtenus avec du riz décortiqué et entier.

Les céréales supplémentées en poisson étaient utilisées en nutrition d'une façon plus efficace, et elles amenaient une meilleure croissance en conséquence de pertes diminuées en azote dans le métabolisme.

Le tableau III présente les résultats pour le riz décortiqué et entier.

Les protéines de ces espèces de poissons sont très riches en acides aminés essentiels; lysine, thréonine, tryptophane et méthionine.

Ce fait peut expliquer l'effet de supplémentation des protéines de ces poissons sur celle des céréales entières et décortiquées qui sont connues pour leur faible teneur en lysine et en tryptophane dans le cas du maïs, et en lysine dans le cas des autres céréales. On en conclura que ces espèces de poissons offrent une haute valeur nutritive, et sont de bons suppléments pour les céréales entières et décortiquées.

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EL VALOR NUTRITIVO DEL "BUFFALO FISH" Y OTROS PECES DE ESTANQUE DE ARKANSAS

Se sabe muy poco del valor nutritivo del "buffalo fish" y otras especies de peces cultivadas en estanque y arrozales en Arkansas.

Este artículo da los resultados de los experimentos de crecimiento y metabolismo con ratas jóvenes alimentadas con raciones compuestas de "buffalo fish" y otras especies de peces como única fuente de proteína. Se incluye un estudio del efecto de reemplazar las proteínas

cereales por las del "buffalo fish"; 1, 3, y 5% de estos sólidos *reemplazaron* cantidades equivalentes de proteína en las raciones de cereales, en las que la concentración de proteína se mantuvo constante. Se realizó otra serie de experimentos sobre los efectos de la *adición* de pequeñas cantidades de estos sólidos que elevaban ligeramente la concentración de proteína. Se determinó el contenido de aminoácidos de las proteínas de estas especies de peces. Los cereales comprendían arroz entero y pulido, harina de arroz integral y pulido, maíz integral y molido, maíz blanco molido, cebada entera y trigo entero y molido.

Los animales tenían de 28 a 32 días de edad. Los experimentos de alimentación *ad libitum* y pareada duraron 70 días. Cada grupo estaba compuesto por 6 machos y 6 hembras que se pesaron semalmente; se tomó nota del consumo diario de alimento. A partir de estos datos se calcularon las relaciones de eficacia de la proteína (REP) que se expresaron como aumento del peso del cuerpo por gramo de proteína ingerida.

Se obtuvieron grandes cantidades de "big mouth buffalo", (*Ictiobus cyprinellus*, Valenciennes), "large mouth black bass" (*Micropterus salmoides*, Lacepede), "red cat fish" (*Ictalurus nebulosus*, Le Sueur), y "gizzard shad" (*Dorosoma cepedianum*, Le Sueur), criados en estanques y arrozales. El conjunto del pescado se congeló, se secó a la temperatura ambiente con ayuda de ventiladores, y se extrajo la grasa con éter de petróleo. El contenido de proteína del "buffalo fish" sin grasa era de 79,1%; el de "bass" de 73,5%; el de "red cat fish" de 76,6%; y el de "gizzard shad" de 59,6%.

En la tabla I se dan los resultados de los experimentos de crecimiento con ratas alimentadas con "buffalo fish" a la concentración de proteína de 9%. El valor obtenido para esta especie se compara favorablemente con los obtenidos para huevo entero, leche entera, sólidos y lactalbúmina de leche en polvo desgrasada, productos considerados como ricos en buena proteína.

Los resultados de los experimentos sobre el valor de suplementación revelan que pequeñas cantidades de proteínas de pescado tenían un efecto suplementario para las proteínas de los cereales enteros y descorticados. La tabla II da los resultados para el arroz pulido y entero.

Los cereales con complementos de pescado se aprovechaban más eficazmente y producían un mayor crecimiento como resultado de las pérdidas más pequeñas de nitrógeno en el metabolismo. La tabla III presenta los resultados para el arroz entero y pulido.

Las proteínas de estas especies de peces son muy ricas en los aminoácidos esenciales: lisina, treonina, triptófano y metionina.

Esto puede explicar el efecto complementario de las proteínas de los cereales enteros y descorticados que son conocidos por su bajo contenido de lisina y triptófano, en el caso del maíz, y de lisina en el de otros cereales. Se llega a la conclusión de que estas especies de peces tienen un alto valor nutritivo, y son buenos complementos de los cereales enteros o descorticados.

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TABLE I

Comparative nutritive value of high protein foods
9 per cent protein level

Ration	*Protein intake*	*Gain*	*Protein efficiency ratio*
	g.	*g.*	
Fish (Buffalo) . .	83·0	177·5	2·14
Chicken meat . .	80·7	169·1	2·09
Whole egg . .	78·9	142·2	1·78
Whole milk . .	72·5	148·3	2·04
Skim milk . .	89·3	187·0	2·08
Lactalbumin . .	72·5	179·0	1·79

TABLE II

Relative supplementary value of fish to rice
Paired feeding

Ration	*Protein intake*	*Gain*	% *increase*	*Protein efficiency ratio*	% *increase*
	g.	*g.*			
White rice . .	36·2	79·2	—	2·18	—
Rice 3% bass .	36·2	91·8	15·9	2·53	16·0
Rice 3% catfish .	36·2	106·8	34·8	2·83	30·0
Rice 3% buffalo .	36·2	132·5	67·4	3·65	67·4
Brown rice . .	43·0	88·8	—	2·06	—
Rice 3% bass . .	43·0	121·3	36·6	2·82	36·9

TABLE III

Effect of buffalo fish on milled and whole rice in metabolism

Ration	*Biological value*	*True digestibility*	*Net protein utilization*	*Increase*
	%	%	%	%
Milled rice . .	72·7	88·7	64·1	-
Rice 3% B.F. . .	89·5	92·9	83·1	29·7
Whole rice . .	86·1	85·7	75·5	-
Rice 3% B.F. .	91·7	93·6	85·8	13·6

TABLE IV

Amino acid content in white milled rice and buffalo fish

	Rice	*Fish*
	%	%
Cystine	0·05	1·50
Lysine	0·22	6·50
Methionine	0·23	2·60
Threonine	0·31	3·70
Tryptophan	0·05	0·80

VALOR BIOLOGICO DE PESCADOS DE CONSUMO EN ESPANA. INFLUENCIA SOBRE EL MISMO DE ALGUNAS TECNICAS DE CONSERVACION

por

G. VARELA, A. PUJOL, y O. MOREIRAS

Se estudia el valor biológico (V.B.) de la proteína por el método de Mitchell en ratas en crecimiento de los siguientes pescados:

(1) Dos crustáceos, langosta (*Palinurus vulgaris*) y gamba (*Parapenaceas longirostris*). Siendo el más elevado el de la langosta (88,2 ± 0,5) que el de la gamba (74 ± 1,6).

(2) Tres moluscos de los que dos eran sin concha, pulpo (*Octopus vulgaris*) y calamar (*Loligo vulgaris*) y uno con concha: chirlas (*Mactra helvacea*). En este grupo el V.B. más elevado es el del pulpo (83,5 ± 0,4), y el más inferior el de las chirlas (77,7 ± 0,5), teniendo un valor intermedio el calamar (81,7 ± 0,6).

(3) Cuatro peces, merluza (*Merlucius merlucius*), corvina (*Sciaena regia* Assolt), rape (*Lophius piscatorius*) y bacalao (*Gadus morrhua*). Encontrándose que el valor biológico más elevado es el de la merluza (88,8 ± 0,3) y el más bajo el bacalao (82,2 ± 1,5). No se observa diferencia significativa entre la merluza fresca (V.B. 88,8 ± 0,3) y la congelada (88,3 ± 0,2). La corvina fresca presenta un V.B. más elevado que la congelada, siendo estos valores 87,9 ± 0,4 y 85,4 ± 0,9 respectivamente. El V.B. de un pescado conservado en salazón, bacalao, cuyo valor es de 82,2 ± 1,5, está comprendido entre el pulpo y el calamar.

La digestibilidad de la harina de Patexo (*Polybius Henslowi* Leach), es de 78,74 ± 2,5, en cuanto a su proteína y de 83,71 ± 1,2 de su grasa. La digestibilidad total de su sustancia seca es de 84,83 ± 0,9. La calidad biológica de su proteína juzgada por su coeficiente de eficacia en crecimiento, es muy deficiente.

En relación con el hielo antibiótico, los resultados obtenidos fueron: Coeficiente de digestibilidad en el gato de la proteína de merluza sin antibiótico 99,1 ± 0,25; con aureomicina 98,8 ± 0,2; con cloromicetina, 98,7 ± 0,1; con penicilina 98,6 ± 0,3; con estreptomicina 98,4 ± 0,4; con biostat HC 95,6 ± 1,8. Por tanto, los antibióticos ensayados no ejercen acción sobre la utilización digestiva de dietas pamproteicas de pescado.

En relación con la digestibilidad de la proteína de merluza frita en las diferentes grasas culinarias, los resultados encontrados fueron según el tipo de grasa utilizada: en mantequilla, 79,36; en margarina, 90,37; en manteca de cerdo, 91,57; en aceite de oliva, 77,16; en aceite de algodón, 85,73; en aceite de soja, 88,79. Los coeficientes de eficacia en crecimiento para la misma proteína fueron: en mantequilla, 2,35; en margarina, 1,94; en manteca de cerdo, 2,04; en aceite de oliva, 2,36; en aceite de algodón, 2,15; en aceite de soja, 2,53.

El valor biológico de la proteína de la sardina fresca es por el método de Mitchell de 71,8; su coeficiente de digestibilidad verdadera de 95,4 y su coeficiente de utilización neta de la proteína, de 68,6.

Para las sardinas conservadas enlatadas en aceite los valores se transforman en:

Valor biológico 73,4; coeficiente de digestibilidad verdadero, 91,0; y coeficiente de utilización neta de la proteína, 66,5.

Por la técnica de Bender y Miller, el valor biológico de las sardinas frescas es de 69, mientras que el de las conservadas enlatadas en aceite, es de 72,7.

BIOLOGICAL VALUE OF THE PROTEIN OF SOME FISHES CONSUMED IN SPAIN. INFLUENCE OF SOME PRESERVATION TECHNIQUES

The biological value of protein in the fish and crustaceans listed below was studied in growing rats, using the Mitchell method:

(1) Two crustaceans, lobster (*Palinurus vulgaris*) and shrimp (*Parapenaceas longirostris*). Here the biological value of the lobster protein was 88·2 ± 0·5 and that of shrimp 74 ± 1·6.

(2) Three molluscs, of which two were without shell; viz. octopus (*Octopus vulgaris*) and squid (*Loligo vulgaris*), and one with shell, viz. "chirlas" (*Mactra helvacea*). In this group the octopus has the highest biological value (83·5 ± 0·4), followed by squid (81·7 ± 0·6) and *Mactra helvacea* (77·7 ± 0·5).

(3) Four fishes: hake (*Merlucius merlucius*), croaker (*Sciaena regia* Assolt), angler (*Lophius piscatorius*) and cod (*Gadus morrhua*). Hake has the highest biological value (88·8 ± 0·3) whilst cod has the lowest (82·2 ± 1·5). There is no significant difference between fresh hake (88·8 ± 0·3) and frozen hake (88·3 ± 0·2). Fresh croaker had a biological value (87·9 ± 0·4) higher than the frozen one (85·4 ± 0·9). The biological value of salted cod (82·2 ± 1·5) is somewhere in between that of the octopus and the squid.

The digestibility of Patexco meal (*Polybius Henslowi* Leach) is 78·74 ± 2·5 (protein) and 83·71 ± 1·2 (fat). The digestibility of all dried matter is 84·83 ± 0·9. The biological quality of the protein, judged by the coefficient of efficiency in growth, is very poor.

In relation with antibiotic ice, the results were as follows: coefficient of digestibility of the hake protein in cats was: (1) without antibiotic 99·1 ± 0·25; (2) with aureomycin 98·9 ± 0·2; (3) with chloromycetin 98·7 ± 0·1; (4) with penicillin 98·6 ± 0·3; (5) with streptomycin 98·4 ± 0·4; (6) with biostat HC 95·6 ± 1·8. It is thus evident that the antibiotics tested have no action on the utilization of fish proteins.

The digestibility of fried hake protein varied according to the type of fat used for drying, as follows:

In butter 79·36; in margarine 90·37; in lard 91·57; in olive oil 77·16; in cotton seed oil 85·73; in soy bean oil 88.79.

For the same protein, the coefficient of efficiency in growth were:

In butter 2·35; in margarine 1·94; in lard 2·04; in olive oil 2·36; in cotton seed oil 2·15; in soy bean oil 2·53.

The biological value of protein from fresh sardines calculated by the Mitchell method was 71·8. The (*true*) digestibility coefficient is 95·4 and the coefficient of net utilization of the protein is 68·6.

For sardines canned in oil, the corresponding values are: biological value 73·4; (*true*) digestibility coefficient 91·0; coefficient of net utilization of protein 66·5.

Applying the Bender and Miller method, the biological value of fresh sardines is 69 whereas in sardines canned in oil it is 72·7.

VALEUR NUTRITIVE DES PRODUITS DE LA PECHE CONSOMMES EN ESPAGNE. INFLUENCE SUR CELLE-CI DE QUELQUES TECHNIQUES DE CONSERVATION

On a étudié la valeur biologique (V.B.) des protéines, par la méthode de Mitchell, sur des rats en croissance et des poissons suivants:

(1) Deux crustacés: la langouste (*Palinurus vulgaris*) et la crevette (*Parapenaceas longirostris*). Il est apparu que la V.B. est plus élevée pour la langouste (88,2 ± 0,5) que pour la crevette (74 ± 1,6).

(2) Trois mollusques, dont deux sans coquilles: sc. le poulpe (*Octopus vulgaris*) et le calmar (*Loligo vulgaris*), et un avec coquille: sc. la "chirlas" (*Mactra helvacea*). Dans ce groupe, la V.B. du poulpe était la plus élevée (83,5 ± 0,4); celle de la "chirlas" la plus basse (77,7 ± 0,5); et celle du calmar en position entermédiaire (81,7 ± 0,6).

(3) Quatre poissons: le merlu (*Merlucius merlucius*), le maigre (*Sciaena regia* Assolt), la baudroie (*Lophius piscatorius*) et la morue (*Gadus morrhua*). La V.B. du merlu (88,8 ± 0,3) est la plus élevée et celle de la morue (82,2 ± 1,5) la plus basse. On ne constate pas de différence significative entre le merlu frais (V.B. 88,8 ± 0,3) et le merlu congelé (88,3 ± 0,2). Le maigre frais présente une V.B. plus élevée qu'à l'état congelé, avec des chiffres respectifs 87,9 ± 0,4 et 85,4 ± 0,9. La V.B. de la morue conservée salée, avec 82,2 ± 1,5, vient se placer entre le poulpe et le calmar.

La digestibilité de la farine de Patexo (*Polybius Henslowi* Leach) est de 78,74 ± 2,5 pour les protéines, et de 83,71 ± 1,2 pour les graisses. La digestibilité totale de sa matière sèche est de 84,83 ± 0,9. La qualité biologique de ses protéines, jugée d'après son coefficient d'efficacité en croissance, est très faible.

En ce qui concerne le rôle de la glace antibiotique, les résultats obtenus ont été:

Coefficient de digestibilité chez le chat des protéines de merlu sans antibiotique, 99,1 ± 0,25; avec auréomycine, 98,8 ± 0,2; avec chloromycétine, 98,7 ± 0,1; avec pénicilline, 98,6 ± 0,3; avec streptomycine, 98,4 ± 0,4; et avec biostat HC, 95,6 ± 1,8. Par conséquent, les antibiotiques essayés n'ont pas exercé d'action sur l'utilisation digestive de régimes protéiques de poisson.

En ce qui concerne la digestibilité des protéines de merlu frit en différentes graisses culinaires, les résultats obtenus ont été les suivants selon les types de corps gras utilisés; dans le beurre, 79,36; dans la margarine, 90,37; dans la graisse de porc, 91,57; dans l'huile d'olive, 77,16; dans l'huile de coton, 85,73; dans l'huile de soja, 88,79.

Les coefficients d'efficacité en croissance pour ces mêmes protéines ont été: dans le beurre, 2,35; dans la margarine, 1,94; dans la graisse de porc, 2,04; dans l'huile d'olive, 2,36; dans l'huile de coton, 2,15; dans l'huile de soja, 2,53.

La V.B. des proteines de la sardine fraiche est de 71,8 selon la méthode de Mitchell; son coefficient de digestibilité vraie est de 95,4 et son coefficient d'utilisation protéique nette est de 68,6.

Pour les sardines en boite, sous huile, les données deviennent: valeur biologique 73,4; coefficient de digestibilité vraie, 91,0; et coefficient d'utilisation protéique nette, 66,5.

Pour la technique de Bender et Miller, la valeur biologique des sardines fraiches est de 69, tandis que celle des sardines en boite sous huile est de 72,7.

This is another illustration of how the scientist with modern methods is helping the production of fish because of its protein value. The illustration shows young carp in a plastic bag at the fresh water fish firm at Chapingo near Mexico City. They are kept alive by oxygen fed through a hose. This is one of the numerous projects of the Mexican Government to increase food production.

TRYPTOPHAN CONTENT OF FISH MEAT WITH SPECIAL REFERENCE TO THE PROTEIN SCORE

by

S. KONOSU and F. MATSUURA

To evaluate the nutritive value of proteinous foods, the conception of protein score was introduced by FAO. The value as low as 70 was adopted as the protein score of fish meat from the content of the first limiting amino acid, (sc. tryptophan), while the fairly higher values, 83 and 86, were respectively given to beef and pork.

The value of tryptophan was entirely derived from the table in the monograph entitled "Amino Acid Content of Foods", edited by Orr and Watt, in which the mean tryptophan content of fish meat was calculated to be 62 mg. per 1 g. of nitrogen, or 0·99 g. per 16 g. of nitrogen, by averaging the values of 169 samples collected from several different sources. This value is, however, considerably low when compared with the values reported by several workers, including the present authors. In addition, the low appraisal for the protein score of fish meat is inconsistent with the view so far generally accepted that the biological value of fish meat compares well with that of beef or pork.

In view of the importance of fish meat as a source of animal protein in Japan, it is desirable to review the tryptophan content of fish meat.

The barium hydroxide digestion was found to give a higher tryptophan value than the sodium hydroxide digestion, when determined by the microbiological method. By using the column chromatographic assay technique at the same time, however, it was proved that the higher value was not due to the incomplete racemization of the amino acid or to the occurrence of interfering substances active for the test organism, *S. faecalis* R.

The amount of tryptophan in raw fish flesh, determined by microbiological test after barium hydroxide digestion, ranged from 1·25 to 1·35 g. per 16 g. of nitrogen; variation among the species was quite small. Tryptophan in canned and salt-dried meat was almost at the same level as that in raw flesh, indicating that such processings as heating and salt-drying do not affect tryptophan to any extent. In addition, it was proved that tryptophan content of fish meat compared well with that of beef, pork or chicken.

It may be concluded that fish meat is as excellent as these domestic animals in supplying tryptophan, and that the protein score of it is not so low as given by FAO, provided that the first limiting amino acid in fish meat is tryptophan.

LA TENEUR EN TRYPTOPHANE DE LA CHAIR DE POISSON EN RELATION PARTICULIERE AVEC LE COMPTE PROTEIQUE (" PROTEIN SCORE ")

Pour évaluer la valeur nutritive des aliments protéiques, la FAO a introduit la notion de "compte protéique". L'on a adopté une valeur aussi basse que 70 pour le compte protéique de la chair de poisson, en se basant sur la teneur du premier acide aminé limitant, (sc. le tryptophane), alors que des valeurs notablement élevées, 83 et 86, étaient respectivement attribuées au boeuf et au porc.

La valeur donnée au tryptophane était entièrement obtenue d'après la table de la monographie "Teneur en amino-acide des aliments" (Amino-acid Content of Foods) éditée par Orr et Watt, dans laquelle la teneur moyenne en tryptophane de la chair de poisson a été calculée comme étant de 62 mg. par g. d'azote (ou de 0,99 g. par 16 g. d'azote) sur la moyenne des valeurs de 169 échantillons réunis depuis des sources différentes. Cette valeur est cependant trop basse, lorsqu'on la compare avec les valeurs présentées par plusieurs chercheurs, dont les auteurs du présent article. De plus, cette faible estimation du compte protéique de la chair de poisson est incompatible avec l'opinion, largement admise, que la valeur biologique de cette chair est bien comparable à celle du boeuf ou du porc.

A l'égard de l'importance de la chair de poisson parmi les sources protéiques animales au Japon, il est souhaitable de réexaminer la teneur en tryptophane de la chair de poisson.

On a trouvé que la digestion à l'hydroxyde de baryum donnait une valeur plus haute en tryptophane que celle obtenue par la digestion à l'hydroxyde de sodium, lorsqu'on employait la méthode microbiologique de détermination. En utilisant dans le même temps la technique d'essai sur colonne chromatographique, on a pu constater cependant que cette valeur plus élevée n'était pas due à une racémisation des amino-acides ou à l'apparition de substances interférentes actives à l'égard de l'organisme-test, *S. faecalis* R.

Le montant de tryptophane dans la chair de poisson brut, déterminé par la méthode microbiologique après digestion à l'hydroxyde de baryum, variait entre 1,25 et 1,35 g. par 16 g. d'azote; les différences entre les espèces étaient très faibles. Le tryptophane dans les chairs en boites ou séchées-salées présentait approximativement les mêmes teneurs que dans le poisson brut, ce qui indique des traitements tels que la cuisson ou le séchage salé n'affectent aucunement le tryptophane. De plus, il a été démontré que la teneur en tryptophane de la chair de poisson était très comparable à celle de la chair de boeuf, de porc ou de poulet.

On peut dire en conclusion que la chair de poisson est aussi excellente que celle des animaux domestiques pour apporter du tryptophane à la nutrition, et que son compte protéique n'est pas aussi faible que ne l'a présenté la FAO, si l'on prend le tryptophane comme premier amino-acide limitant dans la chair de poisson.

EL CONTENIDO DE TRIPTOFANO EN LA CARNE DE PESCADO, CON REFERENCIA ESPECIAL AL COMPUTO PROTEINICO

Al determinar el valor nutritivo de los alimentos proteínicos, la FAO introdujo el concepto del cómputo proteínico, y asignó a la carne de pescado el bajo índice de 70 derivándolo del contenido del primer aminoácide limitante—el triptófano—en tanto que a la carno de buey y de cerdo se daban los índices bastante elevados de 83 y 86 respectivamente.

El valor dado al triptófano se obtuvo enteramente de la tabla de la monografía titulada "Contenido de aminoácido en los alimentos", editada por Orr y Watt, en la que el tenor medio de triptófano de la carne de pescado se calculó en 62 mg. por gramo de nitrógeno, (ó 0,99 g. por 16 gramos de nitrógeno) obteniendo los promedios de los índices de 169 muestras de origen diferente. Sin embargo, este índice es muy bajo, cuando se compara con los comunicados por varios investigadores, incluidos los autores de este artículo. Además, la baja estimación del cómputo proteínico de la carne de pescado es incompatible con la opinión aceptada hasta ahora de que su valor biológico es comparable con el de la de buey o cerdo.

Dada la importancia de la carne de pescado como fuente de proteína animal en Japón, conviene examinar su contenido de triptófano.

Se observó que la digestión con hidróxido de bario daba un índice mayor de triptófano que la digestión con hidróxido de sodio, cuando se determinaba por el método microbiológico. Empleando a la vez la técnica de determinación en columna cromatográfica, se

demostró que el índice más elevado no se debía a la racemización del aminoácido o a la aparición de substancias activas que interferían con el organismo objeto de ensayo, *S. faecalis* R.

La cantidad de triptófano en la carne de pescado bruto, determinada por el método microbiológico después de la digestión con hidróxido de bario, variaba de 1,25 a 1,35 g. por 16 gramos de nitrógeno, siendo muy pequeñas las diferencias entre las especies. La concentración de triptófano en el pescado enlatado y seco en sal era casi igual que en la carne cruda, lo que indica que tratamientos como la cocción y desecación en sal no influyen sensiblemente en el triptófano. Además, se ha demostrado que el contenido de triptófano en la carne de pescado es comparable con el que existe en la de buey, cerdo o pollo.

Se puede decir en conclusión que la carne de pescado es tan excelente como la de estos animales domésticos en el suministro de triptófano, y que el cómputo proteínico no es tan bajo como el que presenta la FAO, a reserva de que el triptófano sea el primer aminoácido limitante de la carne del pescado.

Certainly the scientist must work out the nutritive value of each particular species of fish but that sort of thing is not worrying these people. They are satisfied that "fish is food" as they benefit by and endorse the work of the administration teams in Mexico where the government and FAO's campaign to raise the country's fish consumption achieved outstanding success.

STUDIES ON THE NUTRITIONAL VALUE OF FISH FLESH PROTEINS

by

A. B. MORRISON, E. J. MIDDLETON, H. FOUGERE, and J. A. CAMPBELL

Studies were conducted on the nutritional value of the protein in various samples of fish flour prepared from cod, herring, rosefish and caplin by a modification of the isopropanol extraction procedure of Guttmann and Vandenheuvel (*Prog. Repts. Atl. Coast Stn., Fish Res. Bd. Can.* **67**, 29, 1957). In the modified process, the fish were not de-scaled; the bones were removed by a chloroform flotation procedure, and residual solvent was removed by heating at 100°F. Values for protein efficiency ratio (PER) and net protein ratio (NPR) were determined by the methods of Chapman *et al.* (*Can. J. Biochem. Physiol.* **37**, 679, 1959) and Bender and Doell (*Brit. J. Nutr.* **11**, 140, 1957) respectively. NPR values showed higher coefficients of variation than PER values, and the two procedures did not rank the samples in the same order. The corrected PER value for herring (2·59) was similar to that for casein (2·50), and significantly lower than those for cod, caplin and rosefish (2·80, 2·85 and 2·92, respectively). The NPR procedure ranked rosefish highest and herring lowest, in nutritional value, but gave similar values for caplin and herring.

In further studies, the samples were tested at the 20 per cent protein level. In contrast to results with egg or casein, growth with 20 per cent protein from the various samples of fish flour was no better than that with 10 per cent protein, and the animals given the higher level of fish protein had significantly heavier livers and reduced food consumption. These results indicate that the samples made by the chloroform flotation procedure contained a toxic factor. The toxicity was directly related to the organic chloride content of the samples and could be removed by ether extraction.

It was concluded that processing conditions can markedly influence the nutritional value of fish flour. Since possible toxic effects may appear only at high protein levels, the results also indicate the advisability of testing proteins at more than one level in biological assays for protein quality.

ETUDES SUR LA VALEUR NUTRITIVE DES PROTEINES DE LA CHAIR DE POISSON

On a conduit des recherches sur la valeur nutritive des protéines dans des échantillons divers de farine alimentaire de poisson préparés de la morue, du hareng, de la chèvre et du capelan par un procédé modifié de l'extraction à l'isopropanol décrite par Guttmann et Vandenheuvel (*Prog. Rep. Atl. Coast Stn., Fish Res. Bd. Can.* **67**, 29, 1957).

Dans l'opération modifiée, le poisson n'était pas écaillé; les arêtes étaient enlevées par une méthode de flottation au chloroforme, et le solvant résiduaire était enlevé par chauffage à 100°F (37,7°C). Les valeurs pour le rapport d'efficacité protéique (REP) et le rapport protéique net (RPN) ont été déterminées respectivement par les méthodes de Chapman *et al.* (*Can. J. Biochem. Physiol.* 37, 679, 1959) et Bender et Doell (*Brit. J. Nutr.* **11**, 140, 1957). Les valeurs du RPN ont montré des coefficients de variation plus élevés que les valeurs du REP, et les deux modes opératoires n'aboutissaient pas au même classement des échantillons. La valeur corrigée du REP pour le hareng (2,59) était comparable à celle de la caséine (2,50) et notablement plus basse que celle de la morue, du capelan et de la chèvre (respectivement: 2,80, 2,85 et 2,92). Le procédé de la détermination du RPN classait la chèvre au rang le plus élevé, et le hareng au rang le plus bas, en ce qui concerne la valeur nutritive; mais il donnait des valeurs comparables pour le capelan et le hareng.

Dans des études ultérieures, on a essayé des échantillons au taux protéique de 20 %. Par opposition avec les résultats obtenus avec des oeufs ou de la caséine, la croissance, avec ce taux protéique de 20% pour les divers échantillons de farine alimentaire de poisson, n'était pas supérieure à celle obtenue avec le taux protéique de 10%; et les animaux alimentés au plus haut taux de protéine de poisson présentaient des foies notablement plus lourds et une consommation de nourriture quelque peu réduite. Ces résultats indiquent que dans les échantillons préparés avec le procédé de flottation au chloroforme il y avait un élément toxique. La toxicité était en relation directe avec le contenu de chloride organique des échantillons; on pourrait l'enlever par l'extraction d'éther.

On a conclu de ces recherches que les conditions de fabrication peuvent exercer une influence marquée sur la valeur de la farine alimentaire de poisson. Du fait que des effets toxiques possibles soient susceptibles d'apparaître seulement à de hauts taux protéiques, les résultats montrent également qu'il est sage d'expérimenter les protéines à plus d'un seul taux au cours des essais biologiques qui étudient leur qualité.

ESTUDIOS DEL VALOR NUTRITIVO DE LAS PROTEINAS DE LA CARNE DEL PESCADO

Se estudió el valor nutritivo de la proteína de varias muestras de harina de bacalao, arenque, gallineta y lota por una modificación del procedimiento de extracción con isopropanol de Guttman y Vandenheuvel (*Pro. Reps. Atl. Coast Stn. Fish Res. Bd. Can.* **67**, 29, 1957). En el procedimiento modificado, el pescado no se desescamó; pero las espinas se separaron por un procedimiento de flotación en cloroformo, y el solvente residual se separó por calentamiento a 100°F. (37,7°C). Los índices de la relación de la eficacia de la proteína (REP) y relación de proteína neta (RPN) se determinaron por los métodos de Chapman *et al.* (*Can. J. Biochem. Physiol.* **37**, 679, 1959), y Bender y Doell (*Brit. J. Nutr.* **11**, 140, 1957) respectivamente. Los índices de RPN arrojaron mayores coeficientes de variación que los de REP, y ninguno de los dos procedimientos clasificó las muestras en el mismo orden. El índice de REP corregido para el arenque (2,59) era análogo al de la caseína (2,50), y bastante menor que para el bacalao, lota y gallineta (2,80; 2,85 y 2,92 respectivamente). El procedimiento de REP dio a gallineta el valor nutritivo más alto, y al arenque el más bajo, pero valores análogos para la lota y el arenque.

En estudios ulteriores, las muestras se ensayaron a concentración de proteína del 20%. En contraste con los resultados obtenidos con huevo o caseína, el crecimiento con un 20% de proteína de las diversas muestras de harina de pescado no fue mayor que con un 10% de proteína y los animales que recibieron la concentración mayor de proteína de pescado tenían hígados sensiblemente mayores y consumian menos alimentos. Estos resultados indican que las muestras preparadas por el procedimiento de flotación en cloroformo contenían un factor tóxico. La toxicidad estaba relacionada directamente al contenido de cloruro orgánico de las muestras y podía eliminarse mediante extracción con éter.

Se ha llegado a la conclusión de que las condiciones de elaboración pueden tener un marcado efecto en el valor nutritivo de la harina de pescado. Como puede ocurrir que los posibles efectos tóxicos sólo aparezcan cuando las concentraciones de proteínas son elevadas, los resultados también indican la conveniencia de ensayer las proteínas a más de una concentración en las determinaciones biológicas de su calidad.

THE NUTRITIVE VALUE OF FISH FLOUR AND ITS USE AS A PROTEIN SUPPLEMENT

by

B. C. JOHNSON, V. C. METTA, and H. E. SCHENDEL

The protein quality of an odourless, fat-free fish flour* was evaluated in two ways: (1) the *protein efficiency ratio* (grams gain per gram protein consumed) of the fish flour, present in the diet as 10 per cent of the dietary protein, is 3·24 or 90 per cent of that found for whole egg protein, and better than values reported for skim milk (2·85) or for beef protein (3·15); (2) the Mitchell *biological value* (amount of nitrogen used by the body as a percentage of the nitrogen absorbed) of this fish flour protein (88 per cent) is equivalent to that of milk protein, and better than that of beef protein (78 per cent).

The value of this fish flour as a protein supplement was tested, using simulated East Indian all-vegetable diets. Supplementation at 1 and 3 per cent of the diet markedly improved the growth of rats fed on equal amounts of diet, and thereby also improved the protein efficiency ratios (PER) of the vegetable diets. The improvement in growth is already significant ($p < 0{\cdot}01$) when the fish flour is present as 1 per cent of the diet, and is doubled when present as 3 per cent ($p < 0{\cdot}001$). The increase in growth over that of the controls is 49 per cent at the end of 1 week, and 45 per cent after 4 weeks. Twenty-six Indian students were unable to detect the presence of this fish flour when it was added at a concentration of 3 per cent to 3 different Indian recipes.

In another experiment, using Mitchell's paired-feeding method, we observed that fish flour supplementation improved the PER of a low-protein corn by 17 per cent, and of a high-protein corn by 19 per cent, indicating that an improved amino acid pattern had been achieved.

Besides improving the protein quality, fish flour supplementation will also markedly increase the mineral content of poor diets, especially of rice diets, which are deficient in calcium. For a person eating 20 ounces of food a day, the supplementation of 3 per cent fish flour would provide an additional 459 mg. of highly utilizable fish calcium, which is 60 per cent of a child's requirement.

This fish flour protein was also compared with milk protein in reproduction experiments on rats. Fish flour or casein was the sole source of the protein (19 per cent) for these rats through four generations. The fish flour protein proved as adequate as casein for reproduction through 3 matings of the first generation, 5 matings of the second generation, and 4 matings of the third generation. No differences were observed in the number of litters born, the number of pups weaned, or in their weaning weights. Examination of 11 organs and tissues from animals of the first, second, and third generations revealed no differences between the groups.

All these data support the view that a good fish flour could be of real significance in helping to supply the protein needs of the world.

*Whole fish which were desiccated, defatted, and deodorized by azeotropic solvent extraction by the VioBin Corporation, were used in these studies. This fish flour contained 83 per cent protein ($N \times 6{\cdot}25$) by analysis.

LA VALEUR NUTRITIVE DE LA FARINE ALIMENTAIRE DE POISSON ET SON UTILISATION COMME SUPPLEMENT PROTEIQUE

On a évalué selon deux voies la qualité protéique d'une farine alimentaire* de poisson sans graisse et sans odeur: (1) le *rapport d'efficacité protéique* (REP, en grammes de poids gagnés par gramme de protéines consommées) de la farine alimentaire de poisson, représentant dans le régime 10% de protéines, est de 3,24: c'est-à-dire 90% du REP trouvé pour les protéines d'oeuf entier, et supérieure à ceux qu'on a trouves pour le lait écrémé (2,85) ou pour les protéines de boeuf (3,15); (2) la *valeur biologique* de Mitchell (rapport en % de l'azote utilisé par le corps sur l'azote absorbé) des protéines de cette farine de poisson est équivalente, avec le chiffre de 88%, à celle des protéines du lait et supérieure à celle des protéines du boeuf (78%).

La valeur de cette farine de poisson comme supplément protéique a été expérimentée en utilisant des régimes entièrement végétariens imités de ceux des Indes. Une supplémentation de 1 à 3% du régime améliorait d'une façon nette la croissance de rats nourris de quantités égales du régime de base et, par conséquent, le rapport d'efficacité protéique des régimes végétariens. L'amélioration de la croissance est déjà significative ($p < 0{,}01$) avec 1% de farine de poisson dans le régime, et portée au double avec 3% ($p < 0{,}001$). L'augmentation de la croissance par rapport aux groupes témoins est de 49% à la fin d'une semaine, et de 45% après 4 semaines. Vingt-six étudiants hindous furent incapables de déceler la présence de la farine de poisson, lorsqu'on l'ajoutait dans trois différentes recettes culinaires hindoues à la concentration de 3%.

Dans une autre expérience utilisant la méthode d'alimentation appariée de Mitchell, nous avons observé que la supplémentation en farine alimentaire de poisson améliorait de 17% le REP d'un maïs pauvre en protéines et de 19% celui d'un maïs riche en protéines, ce qui indique qu'on a obtenu une meilleure distribution des amino-acides.

Outre l'amélioration de la qualité protéique, la supplémentation à la farine alimentaire de poisson peut également augmenter d'une façon notable le contenu minéral de régimes pauvres, surtout de régimes à base de riz qui sont déficients en calcium. Pour quelqu'un qui ne consomme que 20 oz. (567 g.) de nourriture par jour, la supplémentation de 3% de farine de poisson pourrait fournir une quantité additionelle de 459 mg. d'un calcium de poisson hautement utilisable, et qui représente 60% des exigences de l'enfant.

On a aussi comparé ces protéines de farine alimentaire de poisson avec des protéines de lait dans des expériences de reproduction chez des rats. La farine de poisson ou la caséine étaient, pour ces rats, les sources uniques de protéines (à 19%) durant quatre générations. Les protéines de farine de poisson se sont montrées aussi convenables pour la reproduction que la caséine, avec 3 accouplements à la première génération, 5 à la seconde et 4 à la troisième. On n'a observé aucune différence dans le nombre de naissances, ni dans le nombre d'animaux arrivant au sevrage, ni dans leur poids au moment du sevrage. L'examen de onze organes et tissus sur les animaux de la première, de la deuxième et de la troisième génération n'a pas révélé de différences entre les groupes.

Toutes ces données soutiennent l'idée qu'une bonne farine alimentaire de poisson pourrait jouer un rôle d'une réelle importance pour aider à satisfaire les besoins protéiques du monde.

*La farine utilisée dans ces études provenait de poisson entier, desséché, dégraissé et désodorisé par extraction azéotropique au solvant par la VioBin Corporation. A l'analyse, cette farine alimentaire de poisson contenait 83% de protéines ($N \times 6{,}25$).

EL VALOR NUTRITIVO DE LA HARINA DE PESCADO Y SU EMPLEO COMO COMPLEMENTO PROTEICO

Se evaluó por dos vías distintas la calidad proteica de una harina de pescado* sin grasa ni olor: (1) la *relación de eficacia proteínica* (gramos de peso ganado por gramo de proteína consumida) de la harina de pescado, presente en la ración como un 10 % de la proteína, es de 3,24 ó 90 % de la encontrada para la proteína del huevo entero, y superior a la observada para la leche descremada (2,85) o para la proteína del buey (3,15); (2) el *valor biológico* de Mitchell (porcentaje de la relación entre el nitrógeno empleado por el cuerpo y el nitrógeno absorbido) de las proteínas de esta harina de pescado (88 %) es equivalente al de la proteína de la leche, y superior al de la proteína de la carne del buey (78 %).

El valor de esta harina de pescado como complemento proteínico se ensayó empleando regímenes enteramente vegetarianos idénticos a los de las Indias Orientales. Un complemento de 1 a 3 % de la alimentación mejoraba netamente el crecimiento de ratas alimentadas con cantidades iguales de la ración básica, y por tanto las relaciones de eficacia de la proteína (REP) de la alimentación vegetariana. La mejora del crecimiento es sensible ($p < 0,01$) cuando la harina de pescado constituye el 1 % de la ración, y se duplica cuando está presente como el 3 % ($p < 0,001$). El aumento del crecimiento, con relación al de los testigos, es de un 49 % al final de una semana y de 45 % después de 4 semanas. Veintiseis estudiantes de la India no pudieron descubrir la presencia de esta harina de pescado, cuando se adicionaba en la concentración de un 3 % a 3 recetas culinarias diferentes de la India.

En otro experimento empleando el método de alimentación pareada de Mitchell observamos que la adición de harina de pescado mejoraba en un 17 % la REP de un maíz pobre en proteínas, y en un 19 % la de un maíz rico en proteínas, lo que indica que se había obtenido una mejor distribución de los aminoácidos.

Además de mejorar la calidad de la proteína, los complementos de harina de pescado pueden también incrementar sensiblemente el contenido de minerales de regímenes alimentarios pobres, particularmente los regímenes a base de arroz que son deficientes en calcio. Para una persona que consuma 20 onzas (567 g.) de alimento al día, la adición de un 3 % de harina de pescado suministraría una cantidad adicional de 459 mg. de calcio de pescado altamente aprovechable, lo que representa un 60 % de las necesidades de un niño.

La proteína de harina de pescado se comparó también con la de leche en experimentos de reproducción con ratas. La harina de pescado o la caseína eran para estas ratas la única fuente de proteína (19 %) durante 4 generaciones. Las proteínas de harina de pescado demostraron ser tan convenientes como la caseína para la reproducción mediante 3 acoplamientos de la primera generación, 5 de la segunda y 4 de la tercera. No se observaron diferencias en el número de nacimientos, el de crías destetadas o en sus pesos al destetarlas. El examen de 11 órganos y tejidos de ejemplares de la primera, segunda y tercera generaciones no revelaron diferencias entre los grupos. Todos estos datos sostienen la opinión de que una buena harina de pescado podría desempeñar un papel de verdadera importancia en la satisfacción de las necesidades de proteína del mundo.

* La harina empleada en estos estudios se preparó con pescado entero, seco, degrasado y desodorizado por extracción con solvente azeotrópico por la VioBin Corporation. Al analizarla esta harina de pescado contenía un 83 % de proteína (N × 6,25).

These Burmese children in Rangoon give practical proof of the attractiveness and nutritive value to health of fish flour. Selected nursery schools were used in the demonstration by the nutritionist of FAO in conjunction with the Burmese Nutrition staff.

ENRICHMENT OF LIME-TREATED CORN FLOUR* WITH DEODORIZED FISH FLOUR

by

RICARDO BRESSANI

In an effort to find a suitable protein concentrate to enrich tortillas made from lime-treated corn, several protein concentrates of animal and vegetable origin were added to the corn at varying levels, and the effects of such supplementation were studied through growth trials with weanling rats, and through nitrogen balance trials in young growing rats.

The minimum levels of the protein concentrates for maximum protein efficiency ratios (PER) were: "VioBin" deodorized fish flour 3 per cent; whole egg protein 3 per cent; INCAP meat flour 4 per cent; nutritional Biochemicals Corporation vitamin-free casein 5 per cent; torula yeast 5 per cent; "Dracket" soybean protein 5 per cent; skim milk 7 per cent; local soybean flour 8 per cent and El Salvador cotton seed flour 8 per cent.

Fish flour added at levels up to 10 per cent of the diet did not lead to any significant improvement in PER beyond that with the 3 per cent addition. Slightly better growth with the 8 per cent fish flour diet was due to its higher protein level. When the basal diet was supplemented with corn gluten to give protein concentrations in the diets equal to those derived from the addition of the other protein supplements, growth increased slightly but the PER decreased. This decrease indicates that the improvement in PER, obtained by the addition of protein supplements or lysine and tryptophan, was due largely to a real improvement in protein quality rather than to higher level of protein in the diets.

In the nitrogen balance studies carried out with young growing dogs, addition of 5 per cent skim milk or 3 per cent torula yeast or 0·17 per cent *L*-lysine HCl plus 0·025 per cent *dl*-tryptophan improved nitrogen retention significantly. The addition of 4 per cent fish flour also improved nitrogen retention during the first four-day balance period. An unexpected decrease in food intake during the second four-day period in all three dogs resulted in a decreased nitrogen absorption and nitrogen retention, when expressed in absolute figures and as percentage of the nitrogen intake. When the nitrogen balance results were calculated as percentages of the nitrogen absorbed, the diet containing fish flour gave better results than did the basal diet.

L'ENRICHISSEMENT DE LA FARINE DE MAIS CHAULE AVEC DE LA FARINE ALIMENTAIRE DE POISSON DESODORISEE

Pour tenter de trouver un concentré protéique convenable qui puisse permettre à l'enrichissement des "tortillas" faites de maïs chaulé on a ajouté à des taux différents plusieurs concentrés protéiques d'origine animale ou végétale; on a analysé les effets d'une telle supplémentation par des études de croissance sur des rats en sevrage et par des études de bilan d'azote sur de jeunes rats en cours de croissance.

Les taux minimum de concentrés protéiques pour obtenir les rapports d'efficacité protéique (REP) maximum ont été: farine alimentaire de poisson désodorisée "VioBin", 3%; protéine d'oeuf entier, 3%; farine de viande INCAP, 4%; caséine nutritive sans vitamines de la Biochemicals Corporation, 5%; levure de torula, 5%; protéine de soja "Dracket", 5%; lait écrémé, 7%; farine de soja local, 8%; et farine de graines de coton El Salvador, 8%.

La farine alimentaire de poisson ajoutée à des taux atteignant 10% du régime alimentaire ne conduisait à aucune nouvelle amélioration du REP par rapport au taux de 3%. Une croissance légèrement meilleure avec un taux de 8% de farine alimentaire était imputable au taux protéique plus élevé. Quand le régime de base était supplémenté avec du gluten de maïs pour obtenir dans les régimes des concentrations en protéines égales à celles qui provenaient de l'addition des autres suppléments protéiques, la croissance augmentait légèrement, mais le REP diminuait. Cette diminution indique que l'amélioration dans le REP, obtenue par l'addition de suppléments protéiques ou de lysine et de tryptophane, était largement due à une amélioration de la qualité des protéines plutôt qu'à des taux élevés de protéines dans le régime.

Dans les études de bilan d'azote conduites sur de jeunes chiens en cours de croissance, l'addition de 5% de lait écrémé ou de 3% de levure de Torula ou de 0,17% de *L*-lysine HCl avec 0,025% de *dl*-tryptophane améliorait d'une façon nette la rétention de l'azote. L'addition de 4% de farine alimentaire de poisson améliorait également la rétention de l'azote au cours des quatre premiers jours de la période de bilan. Une diminution inattendue de la consommation d'aliment au cours des quatre jours suivants de cette période chez tous les trois chiens étudiés s'est traduite par une diminution de l'absorption d'azote et de sa rétention, quand on les exprimait en chiffres absolus et en pourcentages de l'azote consommé. Quand les résultats du bilan de l'azote étaient calculés en pourcentages de l'azote absorbé, le régime qui contenait la farine alimentaire de poisson donnait de meilleurs résultats que le régime de base.

ENRIQUECIMIENTO DE NIXTAMAL CON HARINA DE PESCADO DESODORIZADA

Con objeto de encontrar un concentrado de proteínas adecuado para enriquecer tortillas hechas con nixtamal, al maíz se adicionaron diversas proporciones de concentrados de proteínas animales y vegetales, y los efectos de cada complementación se estudiaron mediante ensayos de crecimiento con ratas recién destetadas y de equilibrio de nitrógeno con ratas jovenes en crecimiento.

Las proporciones mínimas de concentrados de proteína para alcanzar la máxima razón de aprovechamiento fueron: harina de pescado desodorizada "VioBin", 3%; proteína de huevo entero, 3%; harina de carne INCAP, 4%; caseína nutritiva sin vitaminas de la Biochemicals Corporation, 5%; levadura de torula, 5%; proteína de soja "Dracket", 5%; leche descremada, 7%; harina de soja local, 8%; harina de semilla de algodón de El Salvador, 8%.

Adicionar hasta un 10% de harina de pescado a la alimentación, no mejoró la razón de aprovechamiento de la proteína por encima de lo logrado con un 3%. El crecimiento un poco más rápido con la ración que contenía un 8% de harina de pescado se debió a su mayor concentración de proteína. Cuando la ración básica se complementó con gluten de maíz de manera que las concentraciones de proteínas en los alimentos fueran iguales a las obtenidas mediante la adición de otros complementos proteicos, el crecimiento fue un poco más rápido, pero disminuyó la relación de aprovechamiento. Esta disminución indica que la mejora en dicha relación lograda con la adición de complementos proteicos o de lisina y triptófano, se debió principalmente a una mejora real de la calidad de la proteína y no a su mayor concentración en los alimentos.

En los estudios de equilibrio de nitrógeno realizados con cachorros de perro, la adición de un 5% de leche descremada o un 3% de levadura de torula o un 0,17% de *L*-lisina más 0,025% de *dl*-triptófano mejoró sensiblemente la retención de nitrógeno. La adición de un 4% de harina de pescado dio el mismo resultado en los cuatro primeros días del período de equilibrio, pero durante el segundo período de cuatro días disminuyó inesperadamente la cantidad de alimento consumida por los tres cachorros y con ello la absorción y retención de nitrógeno expresados en términos absolutos y como porcentaje del ingerido. Cuando se calcularon los resultados como porcentajes del nitrógeno absorbido, la ración que contenía harina de pescado dio mejores resultados que la básica.

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* In Latin America corn flour which has been treated with lime is known as NIXTAMAL.

NUMEROUS surveys in Latin America have shown that corn is the most important staple food for the rural populations. Table I shows the average daily consumption of corn in several Central American countries, and the average amounts of protein and calories contributed to the diet by this grain (1).

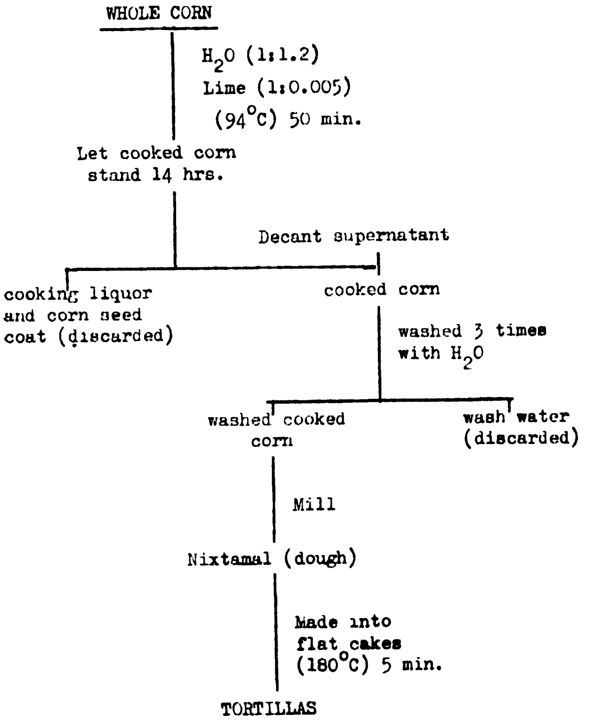

Fig. 1. Method of preparing tortillas in Guatemala.

A great proportion of the corn in Central America is consumed in the form of tortillas made of lime-treated corn. Figure 1 shows how tortillas are prepared in Guatemala (2, 3). The process begins with lime-treating the whole grain; then cooking it, and letting it stand for 14 hours to remove the seed coat and soften the grain. Next, the lime and seed-coat are removed by repeated washing in water. When the grain is clean, it is finely ground, and the dough is patted into flat cakes which are baked for about 3 minutes. Lime-treated corn flour is made by drying and grinding the dough.

TABLE I

Daily quantities of corn consumed in rural areas in central America per person[1]

	Weight	*Calories*	*% of total calories*	*Protein*	*% of total proteins*
	g.			g.	
Costa Rica	185	635	34	15	32
Nicaragua	300	1030	57	24	40
Honduras	398	1370	69	32	48
El Salvador	374	1286	65	30	58
Guatemala	423	1456	64	34	49

[1] Data kindly supplied by Miss Marina Flores, INCAP

TABLEAU I

Quantités de mais consommées par personne et par jour dans les zones rurales de l'Amérique Centrale

TABLA I

Cantidades de maiz consumidas por persona por dia en zonas rurales de América Central

TABLE II

Chemical composition of raw and lime-treated corn

(dry weight)

Nutrient	*Corn*	*Tortilla*
Ether extract, g. %	5·16	2·56
Crude fiber, g. %	1·51	1·21
Nitrogen, g. %	1·52	1·70
Ash, g. %	1·23	1·60
Calcium, mg./100 g.	13	305
Thiamin, mcg./g.	5·40	2·20
Riboflavin, mcg./g.	1·14	0·94
Niacin, mcg./g.	21·61	19·38
Carotene, mcg./g.	3·45	2·40

TABLEAU II

Composition chimique du maïs naturel et du maïs chaulé

TABLA II

Composición quimica del maiz crudo y del nixtamal

This processing of corn causes important changes in the chemical composition of the corn kernel (2, 3). Table II shows the vitamin changes, with significant decreases in thiamin, riboflavin, and carotene, and a slight decrease in niacin. Changes in the amino acid composition are also evident, as shown in Table III, with losses of arginine, histidine, leucine, lysine, and cystine. This Table also compares the amino acid pattern of tortillas and of raw corn with that of the FAO Reference Protein (4), showing that tortilla protein is deficient in lysine, tryptophan and methionine; whilst raw corn is deficient not only in these three but also in isoleucine.

The nutritive quality of the tortilla, as revealed by these data, is extremely poor; and the actual amount of nutritive material utilized by the rural population is even less than dietary surveys indicate. Therefore, in order to provide Central American populations with better quality protein and more vitamins, corn must be enriched.

Before lime-treated corn protein could be successfully enriched, however, it was necessary to determine the minimum of protein-rich foods of animal or vegetable origin which had to be added to it. This was learned by feeding young rats on diets of lime-treated corn, supplemented with increasing levels of protein-rich food. Figure 2 (right side) charts the improvement in nutritive value achieved by adding up to 5 per cent fish flour (5). The optimum supplementation was calculated by drawing two lines, one horizontal, the other diagonal, through as many points (marking various stages of sup-

TABLE III

Essential amino acid composition of raw and lime-treated corn

Amino acid	*Raw corn mg./g. N*	*Lime-treated corn mg./g. N*	*Change %*	*FAO Ref. Prot. mg./g. N*	*Score* *Raw corn*	*Score* *Lime-treated corn*
Arginine	320	260	18·7		—	—
Histidine	170	150	11·7	—	—	—
Isoleucine	260	280	—	270	96	—
Leucine	760	600	21·0	306	—	—
Lysine	190	180	5·3	270	70	67
Methionine	120	120	—	144	68	65
Cystine	64	56	12·5	126		
Phenylalanine	230	240		180	—	—
Tyrosine	240	240	—	180	—	--
Threonine	190	190	—	180	—	—
Tryptophan	31	33	—	90	34	37
Valine	280	300	—	270	-	—

TABLFAU III

Composition en acides aminés essentiels du maïs naturel et du maïs chaulé

TABLA III

Composición en aminoácidos esenciales del maiz crudo y nixtamal

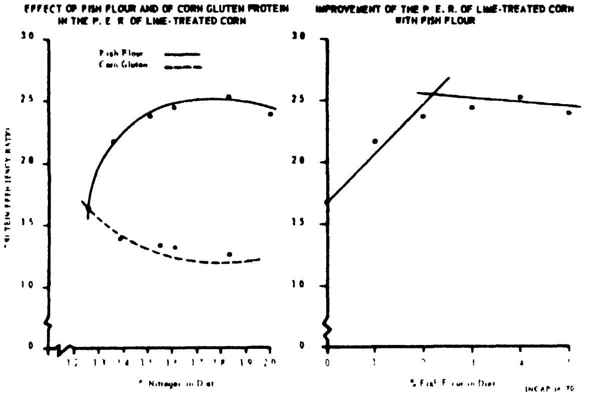

Fig. 2. Shows the improvement effected by adding fish flour.

TABLE IV

Enrichment of lime-treated corn flour with several levels of fish flour and effect of baking on nutritive value of enriched product

Fish flour % of diet	*Protein in diet %*	*Average Final weight g.*	*PER*
	TRIAL 1[1]		
0	9·5	21	1·01
2	11·0	61	1·95
4	12·1	88	2·10
6	13·9	104	2·18
8	15·3	127	2·24
10	17·2	125	2·06
	TRIAL 2[2]		
0 No baking	7·0	18	1·34
2·7 No baking	8·8	68	2·54
2·7 Baking	9·0	59	2·69

[1] Experimental period: 28 days
[2] Experimental period: 21 days

TABLFAU IV

Enrichissement de la farine de maïs chaulé avec des taux différents de farine alimentaire de poisson et effet de la cuisson sur la valeur nutritive du produit enrichi

TABLA IV

Enriquecimiento de nixtamal con diversas cantidades de harina de pescado y efecto de la cocción en el valor nutritivo del producto enriquecido

plementation) as possible. The point of intersection represents the minimum supplementation necessary for maximum improvement in protein quality, which for fish flour is about 2·5 per cent. The left side shows the difference in PER obtained by increasing only the quantity of the protein (adding corn gluten), represented by the dotted line curving down; and by increasing both the quantity and quality of the protein (adding fish flour), as represented by the solid line curving up. It is evident that the nutritive value of lime-treated corn is not improved merely by adding more of the same quality protein.

Table IV shows the average weight gain and PER resulting from additions up to 10 per cent of deodorized fish flour to lime-treated corn. The maximum protein efficiency ratio was reached around the 3 per cent level, as in the previous experiment. Although the higher levels of fish flour did not significantly improve the quality of the protein, the rats gained more weight because of the higher protein levels in the diets.

Since tortillas are baked, tests were also made to determine whether this process altered the nutritive value of lime-treated corn flour enriched with fish flour. Table IV also shows these results, and indicates that baking did not reduce the PER of the enriched flour.

TABLE V

Amount of protein-rich foods, found optimum for supplementing lime-treated corn

Protein-rich Foods	*Amount found % of diet*	*Protein Efficiency Ratio*
None	—	1·00
Egg protein.	3·0	2·25
Casein (V.F.) . .	4·0	2·21
Meat flour . .	4·0	2·34
Fish flour . . .	2·5	2·44
Soybean protein . .	5·0	2·30
Soybean meal . .	8·0	2·25
Cottonseed flour . .	8·0	1·83
Torula yeast . .	2·5	1·97
Pumpkin seed flour .	5·5	1·73

TABLEAU V

Quantités d'aliments riches en protéines, déterminées comme optima pour la supplémentation du maïs chaulé

TABLA V

Cantidad de alimentos ricos en proteinas determinados como óptimos para complementar el nixtamal

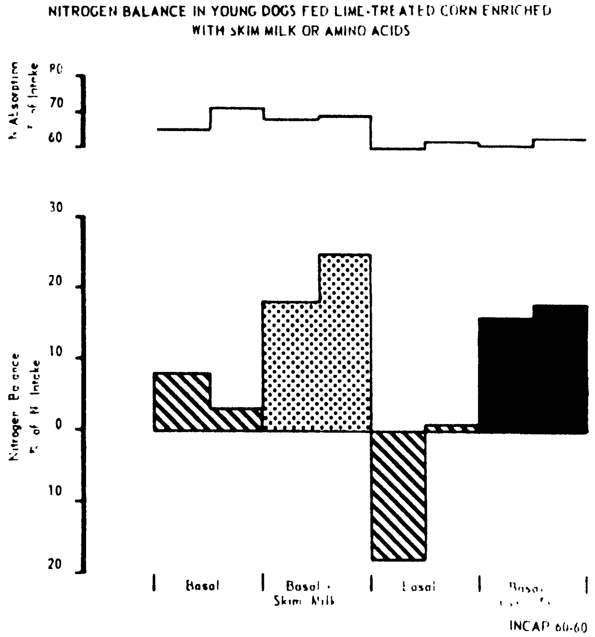

Fig. 3. Reveals the nitrogen balance in young dogs when fed with treated and enriched corn.

Other protein-rich foods were also tested as supplements to lime-treated corn. The results are presented in Table V. Animal proteins in relatively small amounts improved the nutritive value significantly. Among the vegetable proteins, soybean protein and soybean meal improved the nutritive value of lime-treated corn as much as did the animal proteins. Although cottonseed flour, torula yeast, and pumpkin-seed flour also improved the nutritive value, they did not do so to the same degree as did the proteins of animal origin.

The enrichment of lime-treated corn was also studied through nitrogen balance experiments with young growing dogs (6). Figure 3 shows the improvement in nitrogen retention when lime-treated corn was enriched with 5 per cent skim milk or with amounts of lysine and tryptophan equal to those in skim milk.

Table VI shows the nitrogen balance results in dogs fed on diets of lime-treated corn enriched with yeast, skim milk, and fish flour. Both yeast and skim milk improved the balance significantly, but the fish flour supplement did not improve it to the same degree. This lack of response may be attributed to a lower food intake with a consequent lower nitrogen absorption and retention. When the nitrogen retention is expressed on the basis of absorbed nitrogen, however, an improvement is seen.

To check this lowered retention, a third experiment with four growing dogs gave the results shown in Table VII. Skim milk supplementation gave better nitrogen retention values than did the unsupplemented diet. When fish flour was added, there was a significant improvement in nitrogen retention. This shows that the

TABLE VI

Nitrogen balance of dogs fed lime-treated corn flour enriched with various supplements

Average 3 dogs, 8 days/treatment

Supplement	*N Intake mg./kg./day*	*N Absorbed % of intake*	*N Retained % of intake*	*N Retained % of absorbed*
None	729	74·9	13·4	17·9
+ 5% skim milk	745	79·2	33·6	42·4
None	675	77·0	19·5	25·4
+ 3% torula yeast . . .	674	77·7	34·7	44·6
None	539	76·1	24·5	32·2
+ 4% fish flour	454	66·1	26·0	39·3

TABLEAU VI

Bilan de l'azote chez des chiens nourris de farine de maïs chaulé enrichie de suppléments divers

TABLA VI

Equilibrio de nitrógeno en perros alimentados con nixtamal enriquecido con diversos complementos

TABLE VII

Nitrogen balance of dogs fed lime-treated corn flour enriched with various supplements

Average 4 dogs, 8 days/treatment

Supplement	*N Intake mg./kg./day*	*N Absorbed % of intake*	*N Retained % of intake*	*N Retained % of absorbed*
5% skim milk	479	74·5	17·9	24·1
None	494	74·3	12·1	16·3
4% fish flour	480	77·3	31·7	41·0

TABLEAU VII

Bilan de l'azote chez des chiens nourris de farine de maïs chaulé enrichie de suppléments divers

TABLA VII

Equilibrio de nitrógeno en perros alimentados con harina de nixtamal enriquecido con varios complementos

lack of response in the previous experiment was due to a decreased intake of nitrogen.

We can conclude, therefore, that the nutritive value of lime-treated corn protein can be improved by small additions of protein-rich foods of both animal and vegetable origin. Particularly effective were the small additions of fish flour, as evidenced by the increased PER in rats and the high nitrogen retention in dogs.

(INCAP Publication No. I-222).

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Fish flour can be satisfactorily and advantageously mixed with the flour of cereals in the preparation of bread, cakes, etc. Here, the FAO demonstrator, Miss Mary Ross, is showing the staff of the Harcourt Butler Nutrition Institute in Rangoon, some methods of preparation.

EVALUATION OF FISH FLOUR IN THE TREATMENT OF INFANTILE MALNUTRITION*

by

G. G. GRAHAM, J. M. BAERTL, and A. CORDANO

In a group of undernourished infants with and without kwashiorkor, modified cow's milk was used to initiate recovery, to stabilize body composition, and to obtain a steady gain in weight. Subsequently they were given three different bottle feedings at isocaloric and isoproteic levels, recalculated daily: modified cow's milk; vegetable protein mixture of high biological value; and wheat flour enriched with 10 per cent deodorized fish flour, VioBin. One infant had additional periods of fish flour as the sole source of protein. Cottonseed oil and sugar were used to equate the caloric and fat intakes, and minerals and vitamins were added. Growth and nutritional status were studied with the help of nitrogen balance determinations at selected intervals. Growth data along with determinations of serum albumin and urea, hemoglobin and hematocrit, suggest that a mixture of wheat and fish flour, 100 g. of which contain approximately 18 g. of protein and yield 350 calories, satisfies the energy and protein requirements of undernourished infants as well as cow's milk and a mixture of vegetable proteins of high biological value. When fish flour alone was used as the source of protein, the results were equally satisfactory.

In a further group of infants, the wheat-fish flour product was used to initiate recovery with satisfactory results. In one infant, because of large, bulky stools and nitrogen wasting, it was necessary to replace the cottonseed oil with a fat emulsion (Lipomul-Upjohn), noticeably improving absorption.

ETUDE DE LA VALEUR DE LA FARINE ALIMENTAIRE DE POISSON DANS LE TRAITEMENT DE LA MALNUTRITION INFANTILE

Dans un groupe d'enfants sous-alimentés, avec ou sans "kwashiorkor", on a utilisé du lait de vache modifié pour faire démarrer le rétablissement de leur santé, pour stabiliser la composition de leur corps, et pour obtenir un gain de poids constant. On leur a donné ensuite trois biberons différents à des taux isocalorique et isoprotéique recalculés chaque jour: lait de vache modifié, mélange de protéines végétales à haute valeur biologique, et farine de blé enrichie de 10% de farine alimentaire de poisson désodorisée VioBin. Pour un enfant on a fait intervenir des périodes additionelles de farine de poisson comme source unique de protéines. L'huile de coton et le sucre étaient utilisés pour équilibrer la consommation en calories et en graisses, et on a ajouté des minéraux et des vitamines. On a étudié l'état alimentaire et la croissance par mesure du bilan de l'azote à intervalles choisis. Les données de croissance, avec les déterminations de l'albumine du sérum, de l'urée, de l'hémoglobine et des élements centrifugés du sang, permettent de penser qu'un mélange de farine de blé et de farine alimentaire de poisson (dont 100 g. contiennent à peu pres 18 g. de protéines et apportent 350 calories) satisfait les besoins en énergie et en protéines des enfants sous-alimentés, aussi bien que du lait de vache ou qu'un mélange de protéines végétales de haute valeur biologique. Quand on a utilisé la farine alimentaire de poisson seule comme source de protéines, les résultats ont été également satisfaisants.

Dans un groupe d'enfants étudié par la suite, le mélange blé-farine de poisson a été utilisé pour faire démarrer le rétablissement de leur santé, avec des résultats satisfaisants. Chez un enfant, par suite de selles importantes et volumineuses et de perte d'azote, il a été nécessaire de remplacer l'huile de coton par une émulsion grasse (Lipomul-Upjohn) qui a amélioré d'une façon notable l'absorption.

EVALUACION DE LA HARINA DE PESCADO EN EL TRATAMIENTO DE LA MALNUTRICION INFANTIL

En un grupo de niños lactantes, algunos de los cuales padecían de kwashiorkor, se empleó leche modificada de vaca para iniciar la recuperación, estabilizar la composición del cuerpo y alcanzar un aumento constante de peso. Posteriormente, con biberones se les apministraron tres alimentos distintos a concentraciones isocalóricas e isoproteicas que se calculaban a diario y que consistían en leche modificada de vaca, una mezcla de proteínas de origen vegetal de elevado valor biológico y harina de trigo enriquecida con un 10% de harina de pescado desodorizada VioBin. A un lactante se le alimentó, durante períodos adicionales, con harina de pescado como única fuente de proteínas. Se emplearon aceite de semilla de algodón y azúcar para equiparar las absorciones calóricas y de grasas y se adicionaron minerales y vitaminas. El crecimiento y el estado nutritivo se estudiaron a intervalos seleccionados mediante determinaciones del equilibrio de nitrógeno. Los datos de crecimiento y las determinaciones de la albúmina del suero y la urea, hemoglobina y del hematócrito, indican que una mezcla de harinas de trigo y de pescado, 100 g. de la cual contienen aproximadamente 18 g. de proteína y producen 350 calorías, satisfacen las necesidades de energía y proteínas de lactantes desnutridos de iqual manera que la leche de vaca y la mezcla de proteínas de origen animal de alto valor biológico. Cuando sólo se empleó harina de pescado como fuente de proteína, los resultados fueron igualmente satisfactorios.

La mezcla de harinas de trigo y pescado se empleó en otro grupo de lactantes para iniciar la recuperación. Los resultados tambien fueron satisfactorios. En el caso de un lactante, las deposiciones voluminosas y el desaprovechamiento de nitrógeno obligaron a substituir el aceite de semilla de algodón por una emulsión grasa (Lipomul-Upjohn), mejorándose sensiblemente la absorción.

This study was supported by a research grant from the National Institutes of Health (A—4635), U.S. Public Health Service.

AN elevated mortality rate, and the stunted growth of the survivors, are two of the characteristics of underdeveloped nations. Widespread, chronic undernutrition is primarily responsible for both of these problems. Qualitative and quantitative deficiencies of protein are notorious in the diet of Peruvian children, and account for many cases of kwashiorkor in pre-school children, particularly in the second year of life. Significant, overall deficits in caloric intake, notorious in the first year of life, account for many more cases of stunted growth and marasmus. A high rate of illegitimate birth, the many mothers who work to support their children, and the consequent delegation of the care of nursing infants to older siblings and relatives, contribute to infrequent breast feeding and very often to early weaning. The lack of proper substitutes for human breast milk causes many of these infants to starve to death, or to live on in a precarious state of inanition, often reaching their first birthday with the same weight of their birth and very little more body length or maturity.

In many areas of Peru cow's milk is unavailable; where it is, it is usually unsafe and/or beyond the reach of the meager economic capacity of the family. The development of a food or foods which will supply the protein and energy requirements of growing infants and children and which is both inexpensive and yet able to maintain its virtues in transport and storage, is of vital importance to Peru and indeed to other nations with similar problems. It is also important that such foods should be safe and practical to give to nursing infants, and that their mothers should regard them as such.

A food that meets these requirements has already been developed in Central America (1); and considerable progress has been made in Peru toward the development of another vegetable mixture, with similar properties, but made up of locally available ingredients (2). In our estimation, this type of preparation has one major disadvantage, viz. the considerable educational effort that must be made to assure its consumption by a significant part of the population that can most benefit from its use. For this reason, among others, we have been particularly attracted to the possibility of enriching a food which is already consumed by most of the population, even by the nursing infant. Commonly consumed grains, enriched with a deodorized fish flour of high biological value, should satisfy energy and protein requirements, should be inexpensive, easily stored and transported, and readily consumed by all age groups. Preliminary trials with such a product in Mexico (3) have been eminently successful.

In a group of undernourished infants, some with the typical signs of kwashiorkor and others with severe caloric undernutrition or marasmus, we have used modified cow's milk (Similac) to initiate recovery, to stabilize body-composition and to obtain a steady gain in weight. In each case, we tried to determine the minimum intake of protein and calories needed to bring about these changes, providing additional calories in the form of cottonseed oil and table sugar. With some children a casein preparation (Casilan) was used to increase the protein content of the diet. The caloric needs were found to be quite high, depending on the weight deficit. Fairly low intakes of protein were found to be quite adequate, so long as the energy requirement was met (4). Once recovery was initiated and a steady gain in weight established, four different feedings, all given by bottle, were given at isocaloric and isoproteic levels, recalculated daily. As the infants were kept in an air-conditioned environment, it was possible to maintain their water intake at relatively low levels, thus assuring ourselves of nearly 100 per cent intake of the calculated diets.

The four bottle feedings which were used were the following:

(M) Modified cow's milk (Similac), with oil and sugar added as needed.

(V) The vegetable protein mixture of high biological value, referred to above, which has been developed at the Institute of Nutrition of the Ministry of Public Health of Peru. This was cooked with cottonseed oil and sugar in a proportion to match that of the milk preparation. Sodium and potassium salts were added to achieve an intake of 2 and 3 meq. per kg. per day respectively, as in the case of the modified milk. A multivitamin preparation was also given.

(WF) Wheat flour, enriched with 10 per cent deodorized fish flour (VioBin) and made into ordinary noodles, which were cooked in water, and then blended with cottonseed oil and sugar, to achieve the same relative proportions of protein, fat and carbohydrate of the other feedings. Salts and vitamins were added as in the case of the vegetable mixture. The noodles contained approximately 17 per cent protein, roughly half of which was fish protein and half wheat protein, a fact of some importance in the evaluation of results.

(F) Fish flour was given to one infant as the sole source of protein. Cottonseed oil, sugar, salts and vitamins were added as above. With this preparation, although it was well taken and tolerated, there was a distinct odor and taste of fish, which was not at all in evidence with the wheat-fish flour preparation.

The order in which the diets were given was randomized, in order to be able to make valid comparisons. Infants with severe protein deficiency tend to retain nitrogen in the initial phases of treatment, even on inadequate caloric intakes (5), making it difficult to compare this phase of recovery with later phases, particularly in terms of nitrogen retentions.

Growth and nutritional status were studied with the help of nitrogen-balance determinations at selected intervals. All balance periods were of 3 days, and were preceded by an adjustment period of at least 6 days when the diet was changed. In Table I are summarized the results in 6 infants. GG, AG and JV were markedly undernourished, but in relatively good general condition; JV had rather stubborn diarrhea, and a Shigella was repeatedly cultured from his stool, finally clearing up with antibiotic treatment. EA was typically marasmic; AV had all the manifestations of kwashiorkor, and AT was marasmic but also had some edema and sparse, reddish hair.

Weight gains for each infant on the different diets were comparable. Nitrogen absorption (as percent of intake) was similar for milk (M), the wheat-fish flour preparation (WF), and fish flour alone (F); it was slightly lower for the vegetable mixture (V). Nitrogen retentions (as percent of intake) were also similar, with slightly lower

TABLE I

Name, age and wt. at start of diet period			*Days on diet*	*Protein source g. prot./k./d. calories/k./d.*			*Wt. gain g./d.*	*Nitrogen Balance mg./k./d*		
								Intake	*Absorb. (%)*	*Retained (%)*
GG	10m	5·460k	10	M	2·7	130	53			
	11m	5·985k	55	V	2·7	130	38			
	12m	8·050k	15	V	2·0	130	33			
	13m	8·550k	16	WF	2·0	130	33			
EA	10m	4·590k	27	M	2·0	150	41	320		158 (48)
	11m	5·710k	24	WF	2·0	150	44	320		103 (32)
								320		171 (53)
	11m	6·755k	27	V	2·0	150	48	327		160 (49)
								323		114 (35)
								323		117 (36)
AV	27m	8·030k	15	M	2·0	150	49			
	27m	8·760k	19	WF	2·0	150	53			
	28m	9·770k	24	V	2·0	150	41			
AT	13m	6·465k	32	M	1·5	130	45	246	198 (81)	83 (34)
								247	200 (81)	74 (30)
								247	212 (86)	98 (40)
								247	215 (86)	113 (46)
	14m	7·900k	27	WF	1·5	130	32	248	205 (83)	63 (24)
								242	205 (85)	105 (43)
	15m	8·760k	27	V	1·5	130	47	242	194 (80)	100 (41)
								242	181 (75)	63 (26)
								242	168 (69)	62 (36)
AG	7m	5·990k	10	M	3·5	130	29			
	7m	6·280k	61	V	3·5	130	29	557	410 (74)	89 (16)
								558	415 (74)	96 (17)
	9m	8·030k	9	V	2·0	130	33	328	263 (80)	100 (30)
	9m	8·325k	27	WF	2·0	130	34	328	278 (85)	197 (59)
								326	297 (90)	153 (47)
	10m	9·235k	28	F	2·0	130	34	307	289 (93)	164 (54)
								295	240 (81)	118 (40)
	11m	10·200k	13	F	2·0	100	22	300	278 (93)	156 (52)
	11m	10·490k	17	M	2·0	100	19	302	279 (92)	117 (39)
								320	286 (89)	94 (29)
JV	6m	4·555k	5	M	2·0	75	—			
	6m	4·505k	6	M	2·0	100	18			
	6m	4·610k	38	M	2·0	150	30	320	188 (59)	55 (17)
								320	254 (79)	143 (45)
								320	233 (70)	87 (27)
								320	243 (75)	92 (29)
								322	280 (87)	128 (40)
								320	281 (88)	129 (40)
	8m	5·750k	33	V	2·0	150	38	323	189 (59)	54 (17)
								324	235 (73)	87 (27)
								324	238 (73)	113 (35)
								320	230 (71)	94 (29)
	9m	7·000k	29	WF	2·0	150	39	320	259 (81)	116 (36)
								320	267 (83)	135 (42)
								261	208 (80)	85 (33)

values for the vegetable mixture probably reflecting the lower absorption.

Serial determinations of height, bone age (wrist X-rays), nutritional evaluation, hemoglobin, hematocrit, serum albumin, serum urea and other laboratory examinations were done in all cases. The only apparent difference noted to date has been in the serum albumin values, which seem to be lowered in one case from a high normal to a low normal value while on the wheat-fish flour mixture. Recovery of low serum albumin values has also seemed slower with other children while they were on the wheat-fish flour or vegetable mixtures than when they were given milk. Similar observations have been reported by Scrimshaw and Bressani (1) with their vegetable protein mixture. It may be that this represents an imbalance of amino acids in these mixtures. In the one case in which fish flour was given alone as a source of protein, there was a prompt but slight rise in serum albumin. We also have the impression (though we have been unable to document it) that reddish hair returned to a normal color more rapidly on milk than on the other two feedings.

Following our initial experience with these preparations, we have begun to use them to initiate recovery, with generally satisfactory results. These cases are still under study, and are not included in this report. In one infant we did find that large, bulky stools persisted while he was on the wheat-fish flour preparation, making nitrogen retentions very poor. These improved notably when the cottonseed oil was replaced by an emulsified vegetable fat (Lipomul-Upjohn), and improved even further when large daily doses of folic acid were added to the diet. Further experiences with even lower protein intakes have further exaggerated the lag in serum albumin regeneration. These have been rather extreme situations designed to make as critical an evaluation as possible, fully realizing that, although treatment of malnourished infants would never be carried out in such a fashion, the prevention of malnutrition might well depend on very marginal intakes for many infants and children.

Summary

Wheat flour enriched with deodorized fish flour has been compared with a modified cow's milk preparation and with a vegetable mixture of high biological value in the treatment of infantile malnutrition. Similar weight gains and nitrogen retentions suggest that this preparation might well be a good substitute for milk in the diets of infants and children.

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DISCUSSION

On the paper submitted by Prof. Jean Mayer, Mr. D. Hammond (Ghana) remarked that, in view of the problems to which he had already referred under Dr. Rao's paper, it was important to consider in what form fish should be marketed. He believed that those types of fish products for which the consumer had already shown a marked preference should be developed first.

Dr. N. B. Thanh (Viet-Nam): I believe that countries may be classified in two categories: (1) Developed countries, which have well developed agriculture and fisheries; (2) developing countries, which may be further subdivided into (*a*) fish-eating countries, where malnutrition may be solved by developing the fisheries industry, (*b*) non-fish-eating countries, where there are taboos or dislikes for fish. I suggest, nonetheless, that this conference send a recommendation to all developing countries, encouraging them to develop their fish production, processing, and consumption.

Dr. W. M. Chapman (U.S.A.): In the developed countries, we have a highly mechanized fishery where large quantities of fish are produced by relatively small numbers of people; in the developing countries large numbers of people are required to produce a small amount of fish. Production in developing countries can be greatly increased through technological improvements, although this may create severe social problems. What can we do about all those people who are completely dependent on fishing, when suddenly much larger amounts of fish can be produced by a fraction of the people now engaged in this industry?

Dr. K. J. Carpenter (U.K.) asked Dr. G. Varela (Spain): Just how did you prepare your diets for the rat-feeding tests? I presume they were dried before feeding, since it is usually impossible to feed wet material in biological value tests.

Dr. G. Varela (Spain): We did dry all samples before feeding to the rats. We have done some work, however, using cats where wet fish can be fed without drying. Very good results were obtained; e.g. for a biological value of 98·6, several replicates were within 0·2 or 0·3 units of this value.

Dr. O. R. Braekkan (Norway): It is possible to feed rats also on wet fish without drying; but the rats have to be trained to accept restricted diets. This is difficult, but not impossible.

On the paper submitted by Drs. Konosu and Matsuura, Dr. O. R. Braekkan (Norway) asked: Why have you used barium hydroxide for hydrolysis rather than sodium hydroxide?

Dr. S. Konosu (Japan): Barium hydroxide hydrolysis gave a higher value for tryptophan, than sodium hydroxide.

Dr. G. Hamoir (Belgium): Carp muscle yields a protein fraction which does not contain tryptophan. This fraction is approximately 7 per cent of the total protein content of the muscle. A similar fraction appears to occur also in marine fishes. On the other hand, the amino acid composition of the muscle structural proteins (myosin, actomyosin and tropomyosin) does not differ much according to origin. As meat does not contain this "abnormal" protein fraction, the results obtained suggest that the tryptophan content in fish muscle might be somewhat lower than in meat. One cannot, however, exclude the possibility that this lack of tryptophan in some protein of fish myogen could be compensated by a higher percentage of this amino acid in the other easily extracted fish protein.

Dr. B. C. Guha (India): You mean there is no tryptophan in carp muscle?

Dr. G. Hamoir (Belgium): About 7–8 per cent of the protein contains no tryptophan; however, it is possible that tryptophan is found in perhaps the other 92 per cent.

On the papers submitted by Dr. A. B. Morrison and Dr. H. E. Schendel, Dr. K. J. Carpenter (U.K.) observed: Dr. Schendel concluded that the fish flour used in his experiments was of good biological value, because it was better than casein. However, casein itself has no particularly good biological value. Furthermore, reproduction data presented indicate that casein was quite deficient in some important matter, and that the fish flour was only slightly better than casein in maintaining reproduction through successive generations. This may be due to lack of some vitamin, perhaps vitamin B_{12}. In addition, the experiment lacked suitable control groups. All in all, the data presented are not good evidence supporting the high nutritive value of fish flour.

Dr. A. B. Morrison (Canada): I endorse Dr. Carpenter's observation; but it is important to remember also that in studies using commercially produced fish flour there is a great variability between lots, and that the data shown in this paper were from only one lot of fish flour, and not representative of day-to-day production.

Dr. H. E. Schendel (U.S.A.): Dr. Carpenter is correct in his comments that important experiments, such as these tests for the presence of tryptophan in a suggested protein diet source like fish flour, need to be done on a large number of samples from various sources. With regard to the comments that the deterioration of reproduction through successive generations may be due to a vitamin B_{12} deficiency, I can state that I mixed all the diets used in these studies, and can therefore assure the conference that, so far as I know, all known vitamins and minerals, including B_{12}, were present in the diet at optimal amounts. Many workers have observed that rats fed on highly synthetic diets show poor reproduction after approximately three generations on test, possibly due to the absence of unknown growth factors. The fish flour diet provided some factors which helped the rats to perform better over several generations. Other laboratories have also experienced difficulty, as we did, with some sort of pulmonary infection in the rats. There were coughing symptoms in our colony, and this infection may also have played a part in the deterioration of reproduction. However, gross and microscopic examination of tissues did not reveal differences in the lung tissues of rats fed on casein or fish flour.

Dr. D. Snyder (U.S.A.): Dr. Schendel in his summary indicated that the fish flour sample did not contain toxic substances *even* after 18 months' storage at room temperature. With special attention to the word "even", does Dr. Schendel have any reason to believe that toxicity of this fish flour should be expected to increase on prolonged storage?

Dr. H. E. Schendel (U.S.A.): Toxicity might be expected to increase.

Dr. B. Hallgren (Sweden): Preliminary experiments on the effects of chlorinated solvents on fish proteins indicated that in whole small herring, ground, extracted, and dehydrated azeotropically with ethylene dichloride and washed four times with the same solvent, available lysine values decreased from 6·7 to 5·9 per cent. If the product was washed five times with ethanol, available lysine increased to 7 per cent. In another experiment dehydrated fish was extracted five times at room temperature with ethylene dichloride: available lysine then decreased from 6·7 to 5·7 per cent, and after being washed increased to 7·1 per cent. Such an effect of lowering lysine was not observed when the fish was treated with non-chlorinated hydrocarbons, e.g. hexane. These experiments seem to indicate that loose compounds could be formed between certain amino groups of the proteins and chlorinated hydrocarbons.

Dr. A. B. Morrison (Canada): In work with azeotropic processes, fish flours made from either fillets, whole fish, and/or gurry had lower lysine values than flours made by using iso-propyl alcohol as a solvent.

Dr. O. R. Braekkan (Norway): It would be preferable if all analytical data for chlorinated hydrocarbon-content, etc., and the methods of analysis used for obtaining these data, were presented in their entirety.

On the paper submitted by Dr. Graham and his associates, **Dr. H. Westermarck** (Finland) questioned how far it was ever possible to ensure that fish flour was safe for human consumption, because too often certain bacteria (such as Salmonella) were found when samples of flour were examined. He added that the VioBin process, though not yet well known, was of considerable interest and merited further study. He asked whether the superior bacteriological quality of the product could justly be ascribed to the nature of the process.

Dr. G. G. Graham (Peru): Bacteriological examinations were made on all fish flour samples, and no pathogens were ever found.

Mr. H. Loredo (Mexico): There is a general awareness of the importance of fish flour; but does anyone know how much fish meal or fish flour is being consumed by humans today, and whether poor people can afford to buy it? Such organizations as FAO, WHO, and UNICEF should help these people to obtain a cheap nutritious product (one that they can afford to buy).

Dr. J. M. Bengoa (WHO): Graham's paper was impressive. In Chile at present there is a plant capable of producing 300 tons of fish flour for human consumption. This fish flour is suitable for use, not only by children but also by adults. As far as cost is concerned, since only about 5 per cent of fish flour will be incorporated into the total cost of these products, it will not be too high. There are several questions: (1) Why did you use severely undernourished children in your experimental work? (2) Were only moderately undernourished children able to tolerate the mixture used in your experimental work? (3) You mentioned in your report that 10 per cent fish flour is mixed with wheat flour: is this the minimum or maximum level? (4) Could the percentage of fish flour be decreased? If we could use 5 per cent or less, many more children could be benefited by the available fish flour.

Dr. G. G. Graham (Peru): 10 per cent fish flour was chosen arbitrarily; but there is a very good possibility that 5 per cent would be sufficient.

Dr. A. G. van Veen (FAO): FAO and UNICEF are helping the people who are interested in producing fish flour. For example, Morocco has asked for help on some technical aspects. From a bacteriological standpoint, the processes using solvents are usually quite clean bacteriologically. However, careless handling in tropical climates could very easily result in contaminated samples. Price is hard to determine, because of the many factors involved (e.g. cost of labour, raw materials, etc.). However, if fish flour is produced on a large scale, the price need not be more than 12–15 cents per pound, although some producers have mentioned prices as high as $1.00 per pound. A good quality fish flour is not too expensive, if we consider that soybean meal (containing only 40 per cent protein) costs about 6 cents a pound, while fish flour (containing 70–80 per cent of excellent protein) costs not more than 15 cents per pound.

Dr. C. L. Cutting (U.K.): At the Institute for Medical Research at Kuala Lumpur, interesting results in child nutrition were obtained with the use of high protein biscuits containing fish flour, cereal, sugar, and flavouring. Clinic studies of groups of Malayan children showed that, when diet was supplemented with spray-dried skim milk, the rate of gain was twice that of the control group. However, children supplied with fish flour biscuits gained at about three times the rate of the control group. The fact that the biscuits were unpalatable to adults was an advantage in ensuring that the children, who liked them, consumed them. The fish flour need not in this case be deodorized or defatted. But, of course, we should not ignore other methods of fish preservation for tropical conditions, because of the interest in fish flour.

Dr. E. Levin (U.S.A.): The price of the VioBin Corporation product can be fixed at no more than 33 cents per kilo in this country, and only 25 cents per kilo if made in Peru. The consistently good biological value of the product is proved by the fact that several successive batches have been used in various parts of the world. For example, Dr. Gomez has been using fish flour in Mexico for 6 years, with no harmful effects, in groups of 500 children. Tests have also been conducted in Salvador, and commercial products containing fish flour are being used in South Africa and Japan. The VioBin Corporation product contains less than 10 parts per million 1·2-dichloroethane, and less than 10 parts per million alcohol.

Mr. H. Loredo (Mexico): Dried fish would be accepted more readily by the majority of the people. In addition, to judge by the figures given here today, it is cheaper than fish flour.

Dr. I. K. Oryem-Obita (Uganda): Fish meal in Uganda costs twice as much as fish. In Dr. Graham's test the children were in a clinic; there is some doubt whether the same good results would occur in developing countries, where clinical control was not possible.

Dr. H. Fougere (Canada): Fish flour manufactured by the iso-propyl alcohol process would cost about 30 cents per pound in Canada; but this does not take into account possible profits from by-products, such as bone meal or oil. Since fish flour has 80–85 per cent protein, whereas fish has only 20 per cent protein, it looks as if it would really be cheaper to use than fresh fish. Equipment to manufacture fish flour is available in the U.S. today. Regarding the cost of fish flour, however, we have to consider overhead costs, wages, and many other related factors, therefore, cost cannot be precisely determined. The cost in Canada may be higher than the cost in other countries where labour and related items may be cheaper.

Dr. H. Caballero (Chile): The most serious problem we have encountered is that we need to supply protein to the peoples of the world at a price they can afford to pay. For example, in Chile people do not have enough money to buy protein in the form of fish flour. Some people eat too much, some too little. It is difficult to compare countries by their calorie intake.

Dr. W. M. Chapman (U.S.A.): Another problem arose at the FAO Fish Meal Conference in Rome. It was estimated that we would need 5 million tons of edible fish meal to supply the protein needs of the world's underfed people. The extra demand would be equivalent to 25 million tons of raw fish, almost double the present 35 million ton catch. This would create the problem of finding the extra fish needed, and would probably mean the end of selective fishing. Fishermen would have to use the total catch and a new type of industrial fishing operation. In order to utilize all these species of fish, we would need a new form of product, and this product would most likely be fish flour.

Dr. J. Uram (U.S.A.): Fish flour or meal, in contrast with dried whole fish, offers the opportunity of scientifically and economically introducing into the diet an appropriate amount of supplementary amino acid, if necessary. Fish flour also affords easier distribution.

Prof. Dr. M. A. Raafat (U.A.R.): In Egypt we are improving fish consumption by developments in the following areas: (1) improved methods of fishing, especially through mechanization, to increase the catch; (2) the use of refrigerated trains and trucks for transport, which has improved the quality and lowered the price of fish for the consumer; (3) new industries, such as freezing and canning, which are providing a good supply for low income groups; (4) fish-canning residues, which are being used in poultry feeds, and in this way improve human nutrition.

Dr. C. L. Cutting (U.K.): I believe that FAO should consider fish flour as a useful protein source only in appropriate areas, and not as a world-wide panacea for preventing protein malnutrition. Fish flour should have some true fish flavour and texture. A satisfactory flour may need a strong fish taste to be acceptable in some regions, and a bland taste to be acceptable in other regions.

Dr. A. G. van Veen (FAO), who had presented Dr. Mayer's paper in the absence of the author, said to Mr. Hammond (Ghana) that he agreed that fish should be consumed in the form which is most acceptable, so long as the price is sufficiently low. Not only dried and salted, but also smoked or fermented fish may be acceptable in the country. Fish flour might find a place in the diet if there were a special reason for it (e.g. in supplementary feeding schemes, or if there were a surplus of fish on the market). He then replied to Dr. Thanh (Viet-Nam) that the classification which he had proposed could go even further. If in certain countries no fish is eaten, this is not due just to taboos, etc., but very often to the fact that fish production is very low or nil. With the remarks of Dr. Chapman (U.S.A.), he agreed completely; the sociological problems are often overlooked, as FAO knows very well from its world-wide experience, especially in connection with urbanization and industrialization. To Dr. Cutting (U.K.), he replied that FAO has been giving attention to fish flour for many years. In certain areas (for example, in South-east Asia and in Africa south of the Sahara) non-deodorized fish flour is usually preferred; whereas in other regions flavourless fish flour is preferred, such as in a great part of India, Europe and Latin America. FAO has done acceptability-experiments with different kinds of fish flour in many countries. The advantage of fish flour is that it can be packed easily and cheaply in tins, and then does not spoil so easily in tropical climates as, for example, salted and dried fish.

Section 2b : LIPIDS

FISH OILS IN RELATION TO BLOOD CHOLESTEROL AND CARDIOVASCULAR DISEASES

by

HENRIK DAM and ERLING LUND

The relation of serum cholesterol to cardiovascular disease is still a subject for debate. As early as 1843, cholesterol was shown to occur in human atheromatous arteries. Subsequent investigators were able to induce atherosclerosis in rabbits and chicks by feeding them cholesterol. Epidemiological studies in various population groups drew attention to the relationships between high serum cholesterol levels, high incidence of coronary heart disease, and high fat intake. About 10 years ago, studies began stressing the importance of quality of dietary fat in influencing blood cholesterol levels. It was found that blood cholesterol in humans could be lowered by fats rich in polyunsaturated fatty acids, and fish oils were mentioned in this respect. Fish *liver* oils were found to be effective in lowering cholesterol levels; this effect is generally attributed to the high degree of unsaturation of their fatty acids, although some workers found that also vitamin A, in which some of those oils are rich, and the unsaponifiable fraction, exert a lowering influence in hypercholesterolemic patients. The high content of vitamins A and D in fish liver oils makes their common use, in prevention and therapy, quite risky, because of possible overdosage and toxicity from those vitamins.

Fish *body* oils would therefore be preferable to fish *liver* oils. Of fish *body* oils, menhaden oil, although low in essential fatty acids, was found by Ahrens *et al.* to be more efficient than corn oil in markedly lowering serum cholesterol, phospholipids and triglycerides in a hyperlipemic and hypercholesterolemic patient.

The authors observed the effect of menhaden body oil in two patients. A man and a woman with moderately elevated serum cholesterol levels were each given from 10 to 60 ml. per day of highly unsaturated triglycerides from menhaden body oil. This was in addition to an ordinary hospital diet providing 80 g. of fat per day. In the woman, some decrease in blood cholesterol was observed, especially when 60 ml. of menhaden oil were given, while in the man there was a less pronounced decrease. The results seemed to show that short periods of addition of moderate amounts of fish body oil to an ordinary diet containing other fats cannot *a priori* be expected to produce a drastic fall in serum cholesterol.

In another series of experiments, 17 patients received an ordinary hospital diet for 21 days, then a "fish diet" for 28 days, and again the ordinary diet for 4 weeks. The authors found no differences in serum cholesterol values in the three periods.

The mechanism by which polyenoic fatty acids influence the plasma cholesterol concentration is discussed.

The authors conclude that more extensive study is desirable on the value of fish oils in the prophylaxis of cardiovascular disease.

LES HUILES DE POISSON EN RELATION AVEC LE CHOLESTEROL DU SANG ET LES AFFECTIONS CARDIO-VASCULAIRES

La relation entre le cholestérol du sérum et les affections cardio-vasculaires est encore un sujet de discussion. Déjà en 1843 on a montré que le cholestérol était présent dans les artères athéromateuses de l'homme. D'autres chercheurs, plus tard, purent induire une athérosclérose chez des lapins et des poulets en leur faisant ingérer du cholestérol. Les études épidémiologiques sur des groupes de populations variés ont porté l'attention sur les relations qui existent entre des niveaux élevés de cholestérol dans le sérum, la fréquence des coronarites et une ingestion importante de graisses. Il y a dix ans, des recherches commencèrent à mettre l'accent sur l'importance de la qualité des graisses alimentaires a l'égard des taux de cholestérol présentés dans le sang. On trouva que le taux de cholestérol du sang chez l'homme pouvait être abaissé par des matières grasses riches en acides gras polyinsaturés, et on parla à ce sujet des huiles de poisson. Les huiles de foie de poisson se sont montrés efficaces à réduire les taux de cholestérol; cet effet est attribué d'habitude au degré élevé d'insaturation de leurs acides gras, bien que quelques chercheurs aient trouvé également que la vitamine A, dont sont riches quelques-unes de ces huiles, et la fraction insaponifiable exercent une influence d'abaissement sur les taux chez des malades hypercholestérolémiques. La teneur importante en vitamines A et D des huiles de foie de poisson en rend leur emploi très risqué pour une utilisation normale en prévention et en thérapeuthie, par suite de la possibilité d'excès et de la toxicité de ces vitamines.

Les huiles de corps de poisson devraient être préférées, en conséquence, aux huiles de foie de poisson. Parmi ces huiles de corps, l'huile de menhaden, bien que pauvre en acides gras essentiels, a été reconnue par Ahrens *et al.* comme plus efficace que l'huile de maïs pour abaisser d'une façon nette le taux de cholestérol sanguin, de phospholipides et de triglycérides chez un malade hyperlipidémique et hypercholestérolémique.

Les auteurs ont observé l'effet de l'huile de corps de menhaden chez deux patients, un homme et une femme, qui présentaient des taux de cholestérol dans le sérum modérément élevés et à qui on a donné à chacun 10 à 60 ml. par jour de triglycérides hautement insaturées qui provenaient de l'huile de corps de menhaden. Ceci venait en addition à un régime ordinaire d'hôpital, qui contenait 80 g. de matières grasses par jour. Chez la femme, on a observé une certaine diminution dans le cholestérol du sang, surtout lorsqu'on lui donnait 60 ml. d'huile de menhaden; alors que chez l'homme la diminution était moins prononcée. Les résultats semblent montrer qu'avec des additions de courte durée de quantités modérées d'huile de corps de poisson à un régime ordinaire contenant d'autres matières grasses, il ne faut pas s'attendre à une chute brutale du taux de cholestérol sanguin.

Dans une autre série d'expériences, 17 patients ont reçu un régime ordinaire d'hôpital pendant 21 jours; puis un régime à base de poissons durant 28 jours et de nouveau le régime ordinaire durant 4 semaines. Les auteurs n'ont pas trouvé de différences dans les taux de cholestérol sanguin entre les trois périodes.

On commente le mécanisme par lequel les acides gras polyénoïques exercent une influence sur la concentration du cholestérol du plasma.

Les auteurs concluent à la nécessité d'une étude plus étendue en ce qui concerne l'importance des huiles de poisson dans la prophylaxie des affections cardio-vasculaires.

LOS ACEITES DE PESCADO CON RELACION AL COLESTEROL DE LA SANGRE Y LAS DOLENCIAS CARDIOVASCULARES

La relación entre el colesterol del suero sanguíneo y las enfermedades cardio-vasculares continúa siendo tema de controversia. Ya en 1843 se demostró que existía colesterol en las arterias ateromatosas del hombre. Posteriormente los investigadores pudieron inducir la aterosclerosis en conejos y pollos alimentándolos con colesterol. Estudios epidemiológicos de varios grupos de la población pusieron de relieve las relaciones entre elevadas concentraciones de colesterol en la sangre, gran incidencia de enfermedades coronarias del corazón y elevado

consumo de grasas. Hace unos 10 años se iniciaron estudios que pusieron de relieve la importancia de la calidad de la grasa de la alimentación y su influencia en las concentraciones de colesterol en la sangre. Se observó que el colesterol de la sangre de los seres humanos podía reducirse mediante la ingestión de grasas ricas en ácidos grasos con varios enlaces no saturados, y con respecto a ello se mencionaron los aceites de pescado. Se comprobó que los aceites de *hígado* de pescado eran eficaces como reductores de las concentraciones de colesterol; este efecto se atribuye en general al elevado grado de insaturación de sus ácidos grasos, aunque algunos investigadores observaron que también la vitamina A, que abunda en algunos de esos aceites, y la fracción insaponificable, ejercen una influencia reductora en los enfermos hipercolesterémicos. El elevado contenido de vitamina A y D de los aceites de hígado de pescado hace que su empleo correinte en la prevención y terapia sea arriesgado, por ser factible una dosis excesiva y toxicidad de estas vitaminas.

Por estas razones, los aceites del *cuerpo* del pescado serían preferibles a los del *hígado*. De los del *cuerpo*, el aceite de menhaden, aunque bajo en ácidos grasos esenciales, observaron Ahrens *et al.* que eran más eficaces que el aceite de maíz en la reducción sensible del colesterol de la sangre, fosfolípidos y triglicéridos en un enfermo hiperlipémico e hipercolesterolémico

Los autores observaron el efecto del aceite del cuerpo de menhaden en dos pacientes: a un hombre y una mujer, con concentraciones de colesterol en la sangre moderadamente elevadas, fueron administrados de 10 a 60 ml. diarios de triglicéridos altamente no saturados de aceite del cuerpo de menhaden. Esto era en adición a una dieta normal de hospital que suministraba 80 g. de grasa al día. En la mujer se observó cierta disminución en el colesterol de la sangre, especialmente cuando se administraron 60 ml. de aceite de menhaden; pero en el hombre la reducción fue menor. Los resultados parecen demostrar que, si durante períodos cortos se adicionan pequeñas cantidades de aceite de cuerpo de pescado a una dieta normal contenga otras grasas, no puede esperarse *a priori* que se produzca una disminución drástica en el colesterol de la sangre.

En otra serie de experimentos, 17 pacientes recibieron una dieta normal de hospital durante 21 días; después una dieta a base de pescado, durante 28 días; y de nuevo la dieta normal durante 4 semanas. Los autores no observaron diferencia en los índices de colesterol en la sangre en los 3 períodos.

Se examina el mecanismo por el cual los ácidos grasos polienoicos influyen en las concentraciones de colesterol en la sangre.

Los autores llegan a la conclusión de que se tienen que realizar estudios más amplios relativos al valor de los aceites de pescado en la profilaxis de las enfermedades cardiovasculares.

BLOOD cholesterol and its relation to nutrition plays an important rôle in cardiovascular diseases. The occurrence of cholesterol in human atheromatous arteries was discovered by Vogel (45), and Anitschkow and Chalatow (4) produced an experimental atherosclerosis in rabbits by feeding them cholesterol. Dauber and Katz (16) produced a similar condition in chicks by the same means. The important fact that fat greatly facilitates the absorption of cholesterol from the intestine was clearly demonstrated by Cook (14).

Epidemiological studies by Keys and co-workers (24, 25, 26) drew attention to the fact that serum cholesterol and incidence of coronary heart disease are particularly high in population which has a high fat intake.

The importance of the *quality* of the dietary fat, especially vegetable versus animal fat, became evident through the studies of Kinsell *et al.* (29, 30, 31), Groen *et al.* (21), Ahrens *et al.* (1, 2), Bronte-Stewart *et al.* (11), Malmros and Wigand (34, 35), and others.

All the main constituents of dietary fats (the non-saponifiable fraction, the triglycerides, phosphatides and glyceryl ethers) have been considered in relation to blood cholesterol.

The above-mentioned investigators soon became aware of the fact that the *polyunsaturated fatty acids* played an important rôle in lowering plasma cholesterol *in humans*. In this connection, Bronte-Stewart *et al.* (11) mentioned *marine fish oils*. Kinsell and Sinclair (30) particularly called attention to the essential fatty acids.

In 1959, Ahrens *et al.* (2) found a marked lowering of serum cholesterol, phospholipids and triglycerides in a hyperlipemic and a hypercholesterolemic patient, not only when a vegetable oil (notably corn oil) was administered, but also by giving a fish body oil (menhaden oil) which is low in essential fatty acids. Of the two oils examined the fish oil was the more efficient.

Essential fatty acids are those polyunsaturated fatty acids necessary for growth and for prevention of skin symptoms in young rats (Burr and Burr (12)). Thomasson (42) drew attention to the fact that essential fatty acids contain a double bond between carbon atoms 6 and 7 counted from the terminal methyl group. Linoleic and arachidonic acids are the more important essential fatty acids. Linolenic acid is able to sustain growth in rats, but has little effect in preventing skin symptoms (Thomasson, (42)). Unsaturated fish oil fatty acids have been thoroughly examined by Lovern (33), Stoffel and Ahrens (40), and others. Many of the fish oil fatty acids have double bonds arranged according to the "divinylmethane" pattern, which also occurs in the essential fatty acids; but these have only slight, if any, effect as essential fatty acids in rats (Privett *et al.*, (38)). According to Stoffel and Ahrens (40) and Privett *et al.* (38), the menhaden body oil examined by them contained only 2·2 per cent linoleic acid and 0·2 per cent arachidonic acid.

Kingsbury *et al.* (27) examined the influence of ethyl arachidonate, cod liver oil, and a pentane- and hexaene-rich fraction prepared from cod liver oil, in healthy adults and found that all these substances lowered plasma cholesterol.

Many experiments on the influence of fats on serum cholesterol have been carried out with *animals*.

Rabbits are extremely sensitive to the influence of fats of varying degree of unsaturation, and to lack of fat as far as serum cholesterol is concerned. Malmros and Wigand (35) produced hypercholesterolemia and subsequent atherosclerosis in rabbits by means of a fat-free diet. A saturated triglyceride, trilaurin, also produced hypercholesterolemia and atherosclerosis; whereas corn oil, which is rich in linoleic acid, protected.

In *rats* the response of serum cholesterol to fats of varying degree of unsaturation is more complicated. However, when rats are made hypercholesterolemic by hydrogenated coconut oil and cholesterol feeding, cod liver oil and linolenic acid depress serum cholesterol (Hauge and Nicolaysen (23)).

Linolenic acid ethyl ester will also lower serum cholesterol of chicks and hamsters (Dam *et al.*, unpublished).

Chicks fed 1 per cent cholesterol and 10 per cent cod liver oil had lower plasma cholesterol than chicks fed 1 per cent cholesterol and 10 per cent linseed oil (Dam *et al.* (15)).

Whereas the influence of fish oils and other unsaturated oils on plasma cholesterol is generally ascribed to the high degree of unsaturation of some of their fatty acids, some investigators have found that components of the unsaponifiable fraction is also of importance. Wood and Biely (47) and Wood (46) found that in fish liver oils that are very rich in vitamin A, such as halibut liver oil and ling-cod liver oil, vitamin A and therefore also the unsaponifiable fraction as a whole exerts a plasma cholesterol lowering effect in chicks.

Kinley and Krause (28) have found that ingestion of 100,000 i.u. of vitamin A to hypercholesterolemic *patients* lowered the elevated serum cholesterol, whereas in patients with normal serum cholesterol no such effect of vitamin A could be found.

The use of fish liver oils extremely high in vitamin A would not seem to be a suitable remedy for high serum cholesterol, because of the *risk of a toxic effect* of large doses of vitamin A and of an accompanying high amount of vitamin D. Fish *body oil* must therefore be preferred.

As far as other fats are concerned, Beveridge *et al.* (7) point out that the amount of cholesterol occurring in butter increases serum cholesterol in man. The same has been found to be true for rabbits (Funch *et al.*, unpublished). In vegetable oils the phytosterols will to some extent lessen the absorption of cholesterol from the intestine (Peterson (37)).

The effect of the amount of cholesterol occurring in fish oils is usually negligible in comparison with the opposing effect of the unsaturated fatty acids.

We have only a limited experience concerning the use of fish oils in patients, namely with two patients in the Geriatric Unit of the Old People's Town. Two samples of highly unsaturated triglycerides from menhaden body oil were placed at our disposal by the U.S. Fish and Wildlife Service, Seattle, Washington.

The compositions of the two samples of menhaden oil are as follows:

First sample (given 26 January-9 February, 1961):

Dienoic acid . . .	. 2·39 %
Trienoic acid . . .	. 1·27 %
Tetraenoic acid . .	. 7·90 %
Pentaenoic acid . .	. 15·72 %
Hexaenoic acid . .	. 22·03 %
Pref. conj. dienoic acid	. 1·63 %
Iodine value (Wijs) .	. 226

Second sample (given 4 April-13 May, 1961):

Dienoic acid . . .	. 1·57 %
Trienoic acid . . .	. 0·89 %
Tetraenoic acid . .	. 9·39 %
Pentaenoic acid . .	. 13·82 %
Hexaenoic acid . .	. 17·55 %
Pref. conj. dienoic acid	. 2·54 %
Iodine value (Wijs) .	. 220

The fatty acids are determined by the alkali isomerization procedure described by Hammond and Lundberg (22).

The two patients (one man and one woman) had moderately elevated serum cholesterol values. Serum cholesterol was determined twice a week through 190 days. The fish oil concentrates were given in amounts from 10 ml. to 60 ml. per patient per day, in addition to the ordinary hospital diet which has an average fat content of 80 g. fat per day. 24 g. of the fat is ordinary margarine and 10 g. is butter.

In patient No. 1 (Fig. 1) there was some decrease in serum cholesterol, especially during the last period of fish oil ingestion, where 60 ml. was given per day. The increase subsequent to the period with the large amount of fish oil was also evident.

In patient No. 2 (Fig. 2) the effect of fish oil was less pronounced.

These few observations do not, of course, pretend to settle the question as to the value of fish oil treatment as a cholesterol-lowering remedy; but they seem to show that short periods of addition of moderate amounts of fish oil to an ordinary diet containing other fat cannot *a priori*

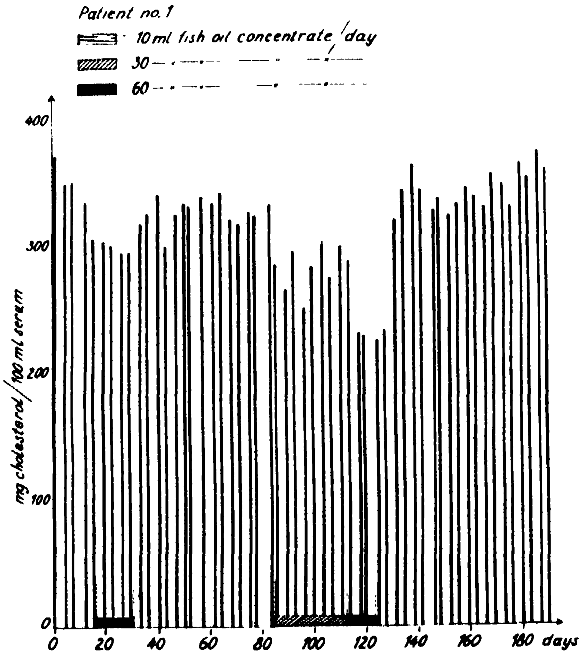

Fig. 1. Some effects of fish oil ingestion (see text).

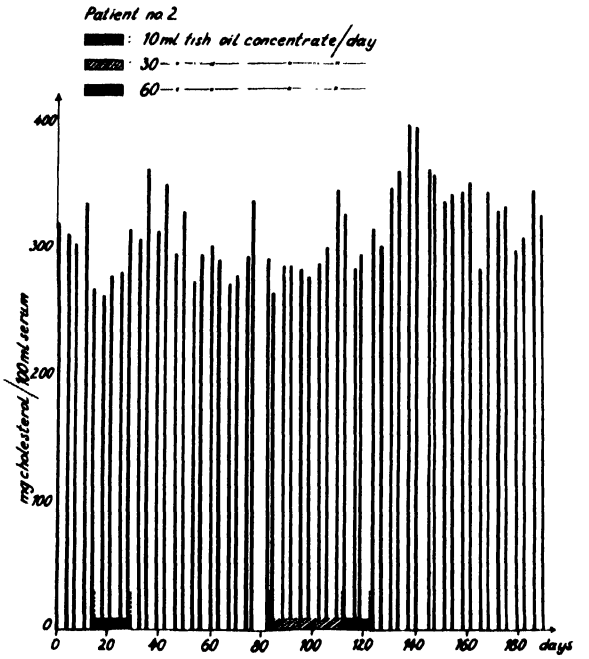

Fig. 2. In this patient the effects were less pronounced (see text).

be expected to produce a drastic fall in serum cholesterol in every case.

In another series of experiments, 17 patients received for 21 days the ordinary hospital diet; then for 28 days "fish diet", but no meat, no eggs, no whole milk or cream; 10 g. of butter and 25 g. of ordinary margarine, and 30 g. of cheese containing less than 3 g. of fat were allowed. Thereafter they received again the ordinary hospital diet for 4 weeks. Fasting serum cholesterol was determined twice a week. The "fish diet" consisted of herring, trout, halibut, mackerel, cod, cod roe or, about once a week, eel, and, rarely, salmon.

No difference in serum cholesterol values could be observed in the various periods.

The *mechanism* through which polyenoic fatty acids influence the plasma cholesterol concentration has not yet been fully elucidated. It is worthwhile to remember that the effect (where there is an effect) sets in fairly rapidly, and that it disappears fairly rapidly when the ingestion of the polyunsaturated fatty acids is suspended. Filling up the tissues with polyenoic acids does not seem to have an effect on plasma cholesterol, when cholesterol is ingested later. This might suggest that the effect depends upon the simultaneous absorption of cholesterol and the fatty acids. It is generally assumed that cholesterol esters ingested with the food become hydrolysed in the lumen of the intestine, whereafter the cholesterol becomes (to a large extent) re-esterified during the passage through the intestinal wall.

A priori one might expect that the polyunsaturated fatty acids would diminish absorption of cholesterol, as compared with saturated or less unsaturated. However, Byers and Friedman (13) found that the amount of cholesterol recovered in the intestinal lymph during 24 hours was greater for cholesterol-dosed rats fed soybean oil or corn oil than for rats fed lard or coconut oil. Thus the more unsaturated oils seemed to cause the greatest absorption of cholesterol. The *excretion* of bile acids during 24 hours in rats was found to be greater when the rats were fed a highly unsaturated oil (walnut oil) than when they were fed coconut oil. Gordon *et al.* (20) found, in humans, that the fall in serum cholesterol due to a highly unsaturated oil (sunflower seed oil) was accompanied by a slight increase of the excretion of neutral sterols and a considerable increase of bile acids in the feces. These changes were interpreted as indication that *the highly unsaturated fat promotes the catabolism and excretion of sterols.* (Bergström (6) had isolated taurocholic acid as the main end-product of cholesterol metabolism in rats.) Alfin-Slater *et al.* (3) suggested that cholesterol, esterified with fatty acids other than polyunsaturated fatty acids, is not available for proper metabolism. It seems likely that the effect of polyunsaturated fatty acids on plasma cholesterol is to be explained in accordance herewith. That the low plasma cholesterol is not caused by retention of cholesterol in the liver has been shown by Frantz and Carey (19). Other investigators have studied the fatty acids in the lipids, especially the cholesteryl esters, of the arterial wall. The results presented by Böttcher *et al.* (8, 9, 10) do not support the hypothesis that the deposition of saturated cholesterol esters is a characteristic feature of atherosclerosis in humans; but Swell *et al.* (41) found that plaques had significantly less linoleic and more oleic acid in that fraction than serum or media. Media and cholesterol ester fatty acids were similar in their fatty acid composition.

Some investigators (Duguid (17), Astrup (5)) emphasized that changes in blood coagulation and fibrinolysis are of primary importance in the development of cardiovascular diseases. The question as to how different dietary fats influence these processes then becomes of interest. Keys *et al.* (25, 26) found that the silicone clotting time of whole blood was significantly shorter after all fatty meals, irrespective of the degree of saturation of the dietary fats, but not after the control carbohydrate meal. Ollendorf *et al.* (36) found a significant hypercoagulability in the blood during a period on a diet rich in soya-bean oil in comparison with periods on normal diet and on a diet rich in butterfat. Scott and Thomas (39) found that butter markedly and significantly prolonged lysis time of human plasma, whereas corn oil and coconut oil had less effect.

So far we have mainly considered fats from the point of view of degree of unsaturation of the fatty acids. The chain length of the fatty acids is, however, also of some importance, especially in connection with marine oils, which contain a considerable proportion of fatty acids with 20 and 22 carbon atoms. According to Thomasson (43, 44) the long chain fatty acids (C_{20}, C_{22}) are more slowly absorbed and remain longer in the intestine than those with a shorter chain length.

Ill-effects resulting from the feeding of highly unsaturated fish oils (such as tuna oil, sardine oil, menhaden oil or cod liver oil) at a level of 10 per cent of the diet to rats have been reported by Ershoff (18). They were diarrhea and growth retardation. It is likely that they were, at least to a large extent, caused by autoxidation products of the fatty acids, since they could be partly prevented by simultaneous ingestion of free α-tocopherol or other antioxidants. Further, it is known that highly unsaturated fats, fed together with a diet containing an insufficient amount of vitamin E, produce various drastic diseases in animals. Highly unsaturated fat should not be given without sufficient vitamin E.

Feeding of diets with 20 per cent cod liver oil to chicks caused severe liver damage which could not be prevented by any amount of α-tocopherol acetate (Dam and Søndergaard, unpublished).

In conclusion, it seems that ingestion of fish oils, as well as other highly unsaturated fat, is worthwhile considering as one of several factors in the prophylaxis against cardiovascular disease. However, it is necessary to carry out more extensive studies of this problem.

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COMPARATIVE EFFECTS OF MARINE OILS, MARINE OIL FRACTIONS AND WHOLE FISH MEALS ON HYPERCHOLESTEREMIC RATS

by

JAMES J. PEIFER

Various investigators have found that the inclusion of certain unsaturated fats in the diet will promote a reduction in the blood cholesterol levels of atherosclerotic patients and experimental animals. Our previous studies with hypercholesteremic rats have demonstrated that marine oils, such as tuna and menhaden oils, are more effective cholesterol depressants than linoleate, an essential fatty acid (EFA) and the most abundant polyunsaturated fatty acid found in our common dietary fats (Peifer, *et al.*, *Arch. Biochem. Biophys.*, 86, 1960). From the results of these experiments it was apparent that the depression of the blood cholesterol levels of the rat was not dependent upon either the availability of significant quantities of EFA or upon the exclusion of non-essential unsaturated fatty acids from the diet. The complex mixture of fatty acids and non-saponifiables found in the two marine oils satisfied the rat's requirements for a rapid and significant reduction in the cholesterol levels of the blood. Further researches have revealed that the cholesterol depressant activities of tuna, menhaden and dog-fish liver oils are a reflection of the metabolic activities of the fatty acid components of these oils. The non-saponifiables of these marine oils had little effect on the hypercholesteremic condition of the rat. Glyceryl ethers, the non-saponifiable components commonly found in shark liver oils, had no apparent effects on the circulating cholesterol levels of the rat. In an attempt to establish the chemical nature of the fatty acid components responsible for the observed activity of marine oils, the esters prepared from menhaden oil fatty acids were separated into a series of fractions differing in their relative degrees of unsaturation. These marine oil ester fractions were found to be more effective than common dietary fats and oils in reducing the blood and liver lipids of the hypercholesteremic rat (*Federation Proceed.*, **20**, 93, 1961). The relative effects of the ester fractions and the dietary fat supplements were not directly related to the total unsaturation of these oils. The menhaden esters were far more effective in reducing the tissue lipids of the rat than could be predicted on the basis of the total unsaturation of these fractions.

Although commercially prepared marine oils are effective agents for reducing blood cholesterol levels in man and experimental animals (Ahrens; Bronte-Stewart; Hauge; etc.), a more practical form of supplying such oils would be the ingestion of fish products containing the marine oils. Hypercholesteremic rats fed with whole fish meal from menhaden, mullet, salmon and perch, showed a rapid and significant reduction in their circulating lipids. These effects were duplicated by feeding rats equivalent amounts of the marine oils extracted from the meal. The non-lipid components of the fish meal had no apparent effects on the circulating lipids of the rats.

Notes: 1. A detailed description of many of these researches is included in a series of manuscripts being prepared for publication.

2. These researches were supported by the Fish and Wildlife Service of the U.S. Department of Interior, the American Heart Association, and the National Institutes of Health.

3. The author is an Established Investigator of the American Heart Association and Research Associate of the University of Minnesota.

EFFETS COMPARES DES HUILES D'ORIGINE MARINE, DE LEURS FRACTIONS ET DES FARINES TOTALES DE POISSON SUR LES RATS HYPERCHOLESTEREMIQUES

Divers chercheurs ont trouvé que la présence de certaines graisses insaturées dans le régime alimentaire amène une réduction des taux de cholestérol sanguin chez certains patients atteints d'athérosclérose et chez des animaux d'essais. Nos études antérieures sur des rats hypercholestérémiques ont démontré que les huiles d'origine marine, telles que les huiles de thon et de menhaden, étaient des agents abaisseurs de cholestérol plus efficaces que le linoléate, un acide gras essentiel (AGE) et l'acide gras polyinsaturé le plus abondant trouvé dans les graisses de nos régimes habituels (Peifer, *et al.*, *Arch. Biochem. Biophys.*, 86, 1960). D'après les résultats de ces expériences, il était apparent que l'abaissement des taux de cholestérol sanguin chez le rat ne dépendait ni du fait que des quantités notables d'AGE soient disponibles, ni du fait que des acides gras insaturés non essentiels soient exclus du régime. Le mélange complexe des acides gras et des insaponifiables trouvés dans les deux huiles d'origine marine répondaient chez les rats aux exigences nécessaires pour obtenir une réduction rapide et significative des taux de leur cholestérol sanguin. Des recherches ultérieures ont révélé que les activités d'abaissement du cholestérol des huiles de foie de thon, de menhaden et de dog-fish réfléchissaient les activités de métabolisme des acides gras composants de ces huiles. Les insaponifiables de ces huiles avaient peu d'effet sur l'état hypercholestérémique du rat. Les éthers glycériques, composants insaponifiables communs des huiles de foie de requin, n'avaient pas d'effets apparents sur les taux de cholestérol circulatoire chez le rat. Dans le but d'établir la nature chimique des composants acides gras responsables de l'activité observeé des huiles d'origine marine, on a séparé les esters préparés depuis les acides gras d'huile de menhaden en une série de fractions différant dans leur degré relatif d'insaturation. Ces fractions d'esters d'huiles d'origine marine se sont montrées plus efficaces que les graisses et les huiles diététiques communes pour réduire les lipides du sang et du foie chez le rat hypercholestérémique (*Federation Proceed.*, **20**, 93, 1961). Les effets relatifs de ces fractions d'esters et des suppléments de graisses diététiques n'étaient pas en relation directe avec l'insaturation totale de ces huiles. Les esters d'huile de menhaden étaient bien plus agissants pour réduire les lipides des tissus chez le rat qu'on aurait pu le prévoir d'après l'insaturation totale de ces fractions.

Bien que les huiles commerciales d'origine marine soient des agents efficaces pour réduire les taux de cholestérol sanguin chez les hommes et les animaux d'essai (Ahrens; Bronte-Stewart; Hauge; etc.), une façon plus pratique de fournir ces huiles consisterait à faire ingérer des produits du poisson qui les contiennent. Des rats hypercholestérémiques alimentés avec des farines totales de menhaden, de mulet, de saumon et de perche montraient une réduction rapide et significative de leurs lipides circulatoires. Ces effets ont été reproduits en alimentant les rats avec des quantités équivalentes d'huiles extraites de ces farines. Les composants non lipidiques des farines de poisson n'amenaient pas d'effets apparents sur les lipides circulatoires chez les rats.

Notes: 1. Une description détaillée de la plupart de ces recherches est comprise dans une série de manuscrits en cours de préparation pour leur publication.

2. Ces recherches ont été subventionnées par le Fish and Wildlife Service du Department of Interior des E.-U., l'American Heart Association et les National Institutes of Health.

3. L'auteur est un chercheur permanent de l'American Heart Association et associé de recherches de l'Université du Minnesota.

EFECTOS COMPARATIVOS DE LOS ACEITES MARINOS, FRACCIONES DE ACEITES MARINOS Y HARINAS DE PESCADO INTEGRALES EN RATAS HIPERCOLESTEREMICAS

Varios investigadores han observado que la inclusión de ciertas grasas no saturadas en la alimentación promueve una reducción de las concentraciones de colesterol en la sangre de enfermos de aterosclerosis y animales experimentales. Nuestros estudios previos con ratas hipercolesterémicas han demostrado que los aceites de origen marino, tales como los de atún y lacha, son deprimentes del colesterol más eficaces que el linoleato, un ácido graso esencial, y el más abundante de los ácidos grasos con varios enlaces no saturados que se encuentran en las grasas corrientes de nuestra alimentación (Peifer *et al.*, *Arch. Biochem. Biophys.*, 86, 1960). De los resultados de estos experimentos se dedujo que la reducción de las concentraciones de colesterol en la sangre de la rata no dependía de la disponibilidad de cantidades sensibles de un ácido graso esencial ni de la exclusión de ácidos grasos no saturados no esenciales. La mezcla completa de ácidos grasos y substancias no saponificables encontradas en dos aceites marinos, satisfizo la necesidad de la rata de una reducción rápida e importante en las concentraciones de colesterol en la sangre. Investigaciones ulteriores han revelado que las actividades deprimentes del colesterol de aceites de hígado de atún, lacha, y cazón son un reflejo de las actividades metabólicas de los ácidos grasos componentes de estos aceites. Las substancias no saponificables de estos aceites marinos tenían poco efecto en el estado hipercolesterémico de la rata. Los éteres de glicerilo, o compuestos no saponificables encontrados normalmente en los aceites de hígado de tiburón, no tenían efectos aparentes en las concentraciones de colesterol en el sistema circulatorio de la rata. En una tentativa de establecer la naturaleza química de los ácidos grasos componentes causantes de la actividad observada en aceites marinos, los ésteres preparados a partir de ácidos grasos del aceite de lacha se separaron en una serie de fracciones que diferían en sus grados relativos de insaturación. Estas fracciones de ésteres de aceites marinos resultaron ser más eficaces que las grasas y aceites de la alimentación corriente en la reducción de los lípidos de la sangre e hígado de la rata hipercolesterémica (*Federation Proceed.*, **20**, 93, 1961). Los efectos relativos de las fracciones de los ésteres y de los complementos grasos de la alimentación no estaban relacionados directamente a la insaturación total de estos aceites. Los ésteres del aceite de lacha eran mucho más eficaces en la reducción de los lípidos de la rata de lo que podía anticiparse basándose en la insaturación total de estas fracciones.

Aunque los aceites marinos del comercio son agentes eficaces en la reducción de las concentraciones de colesterol en el hombre y los animales experimentales (Ahrens; Bronte-Stewart; Hauge; etc.), una forma más práctica de suministrar estos aceites sería mediante la ingestión de los productos pesqueros que los contienen. Las ratas hipercolesterémicas alimentadas con harinas integrales de lacha, mújol, salmón y perca experimentaron rápidamente una reducción significativa en los lípidos de la sangre. Se consiguieron exactamente los mismos efectos alimentando a las ratas con cantidades equivalentes de los aceites marinos extractados de las harinas. Los compuestos no lipídicos de las harinas de pescado no tenían efectos aparentes en los lípidos de la sangre de las ratas.

Notas: 1. Una descripción detallada de muchas de estas investigaciones aparece en una serie de manuscritos que se preparan para la publicación.

2. Estas investigaciones las apoyaron el Servicio de Caza y Pesca de la Secretaría Interior de los E.U.A., la "American Heart Association" y el "National Institutes of Health".

3. El autor es investigador permanente de la American Heart Association y asociado de investigaciones de la Universidad de Minnesota.

THE RELATION OF FISH AND FISH PRODUCTS TO PLASMA LIPIDS AND POSSIBLY TO ATHEROGENESIS

by

L. W. KINSELL

That polyunsaturated fat derived from vegetable oil, as well as synthetic ethyl linoleate and triolein, will appreciably lower the level of the circulating plasma lipids has been well demonstrated. This observation raises various questions, such as:

(1) Is this effect limited to polyunsaturated fatty acids which are known to be essential, at least in the growing rat?

(2) If so, does elevation of plasma lipids represent a manifestation of essential fatty acid deficiency, at least in some instances?

Recent work has indicated that the highly unsaturated fats, derived from fish and containing little or no "essential fatty acids", are capable of producing a major decrease in the level of circulating plasma lipids when ingested by normal and abnormal human subjects. This seems to indicate that the plasma-lipid-lowering effect of unsaturated fats is not related to the essentiality of the polyunsaturated fatty acids which they contain, and that therefore hyperlipidemia is not a manifestation of essential fatty acid insufficiency.

Recent studies in our laboratory, including silicic acid chromatography for separation of the plasma lipids, and gas chromatography for quantitative determinations of the individual fatty acids composing the different plasma lipid fractions, have shown that different fractions of fish oils produce differing effects on the level of plasma lipids. Specifically, a fraction with an iodine value in excess of 300 has been shown to have a major hypolipidemic effect. The two chief components of this fraction are a pentaenoic C^{20} fatty acid and a hexaenoic C^{22} fatty acid. In the cholesterol ester fractions of some of the patients receiving this material, highly unsaturated fatty acids, not identical with the fatty acids fed, have been noted. In some instances there seems to have been an increase in arachidonic acid. Highly unsaturated fatty acids have also been noted at times in some of the other plasma lipid fractions.

Studies have shown that mixed diets containing large amounts of fish have produced much lower plasma lipid levels than diets of approximately equal protein and fat content derived from meat and dairy products. Further studies using quantitatively constant diets are currently being made in patients under precisely controlled conditions on the metabolic ward.

On the basis of these observations it seems that the ingestion of fish and fish derivatives is associated with relatively and absolutely low levels of plasma lipids, as compared with diets containing little or no fish. There is also a suggestion that some of the "non-essential" polyunsaturated fatty acids of fish, when consumed by the adult human, are transformed to polyunsaturated fatty acids which are "essential".* It cannot, therefore, be categorically stated that the effect of polyunsaturated fatty acid upon plasma lipids is unrelated to essentiality. In view of the relationship between elevated plasma lipids and predisposition to coronary heart disease and other manifestations of atherosclerosis, there is every reason to evaluate critically the place of fish in the dietary with particular reference to the possibility of a desirable effect upon production or progression of degenerative vascular disease.

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* Since presentation of this paper it has been demonstrated that the fatty acid with an approximate retention time of the C 20 : 4 standard is *not* arachidonic acid.

LES RELATIONS DES LIPIDES DU PLASMA ET, PROBABLEMENT, DE L'ATHEROGENESE AVEC LE POISSON ET LES PRODUITS DU POISSON

Il a été largement démontré que les graisses polyinsaturées dérivées des huiles végétales peuvent abaisser d'une façon appréciable et aussi bien que la linoléate d'éthyle synthétique et la trioléine, le taux des lipides circulatoires du plasma.

Cette observation soulève diverses questions, dont les suivantes:

(1) Est-ce que cet effet est limité aux acides gras polyinsaturés que l'on sait bien être essentiels, au moins chez le rat en cours de croissance?

(2) S'il en est ainsi, est-ce que l'élévation des lipides du plasma représente une manifestation d'une déficience en acides gras essentiels, au moins dans certains cas?

Des études récentes a montré que les graisses hautement insaturées, dérivées du poisson et contenant peu ou pas d'acides gras essentiels, sont capables de produire une diminution importante du taux de lipides circulatoires du plasma, quand elles sont ingérées par des sujets humains, normaux ou anormaux. Cela semble indiquer que l'effet d'abaissement des lipides du plasma présenté par les graisses insaturées n'est pas relié au caractère essentiel des acides gras polyinsaturés qu'elles contiennent et que, par conséquent, l'hyperlipidémie n'est pas une manifestation d'une déficience en acides gras essentiels.

Des experiences conduites il y a peu de temps dans notre laboratoire, qui comprennent la chromatographie à l'acide silicique pour la séparation des lipides du plasma et la chromatographie en phase gazeuse pour la mesure quantitative des acides gras individuels qui composent les différentes fractions des lipides du plasma, ont montré que des fractions différentes d'huiles de poisson produisent des effets dissemblables sur le taux des lipides du plasma. En particulier, une fraction, dont l'indice d'iode excédait 300, a présenté un effet hypolipidémique très important. Les deux composants principaux de cette fraction étaient un acide gras penténoïque en C^{20} et un acide gras hexanoïque en C^{22}. Dans les fractions d'ester de cholestérol chez quelques-uns des patients qui recevaient ce produit, on a noté des acides hautement insaturés qui n'étaient pas identiques aux acides gras ingérés. Dans quelques cas, il a semblé qu'il y ait eu une augmentation de l'acide arachidonique. Des acides gras hautement insaturés ont été également notés par instants dans quelques-unes des autres fractions de lipides du plasma.

Des études ont montré que des régimes mixtes, contenant de grandes quantités de poisson, avaient amené des teneurs en lipides du plasma bien plus basses que des régimes dérivés de viandes et de produits laitiers, et dont la teneur en protéines et en graisses était à peu près identique. Des études ultérieures avec des régimes quantitativement constants vont se poursuivre normalement sur des patients en chambre d'observation du métabolisme sous des conditions contrôlées précises.

Sur la base des observations précédentes, il semble que l'ingestion de poisson et de produits dérivés du poisson s'accompagne, en valeur relative et absolue, de niveaux bas de lipides du plasma, en comparaison avec des régimes contenant peu ou pas de poisson. On est conduit également à penser que quelques-uns des acides gras polyinsaturés "non-essentiels" du poisson se transforment, lorsqu'ils sont consommés par l'homme adulte, en acides gras polyinsaturés "essentiels".* Par conséquent, on ne peut pas affirmer d'une façon catégorique que l'action des acides gras polyinsaturés sur les lipides du plasma ne soit pas reliée au fait d'être essentiels. Devant les relations existant entre des teneurs élevées en lipides du plasma et une prédisposition aux coronarites et autres manifestations de l'athérosclérose, il y a une raison importante d'évaluer d'une façon critique la place du poisson en diététique, en tenant compte particulièrement des possibilités d'obtenir un effet heureux à l'égard de l'apparition ou la progression des maladies de dégénération vasculaire.

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* Depuis la présentation de cet article, on a démontré que l'acide gras qui présente le temps de rétention approximatif de la norme C 20 : 4 *n'est pas* l'acide arachidonique.

RELACION DEL PESCADO Y LOS PRODUCTOS PESQUEROS CON LOS LIPIDOS DEL PLASMA Y, POSIBLEMENTE, CON LA ATEROGENESIS

Se ha demostrado claramente que las grasas con varios enlaces no saturados procedentes de aceites vegetales, así como el etilinoleato y trioleína sintéticos, reducen sensiblemente la concentración de lípidos en el plasma sanguíneo. Esta observación plantea varias cuestiones, entre las que están:

(1) ¿Se limita este efecto a los ácidos grasos con varios enlaces no saturados de los que se sabe son esenciales por lo menos para la rata en crecimiento?

(2) De ser éste el caso, ¿representa el aumento de la concentración de lípidos del plasma una manifestación de deficiencia de ácidos grasos esenciales, por lo menos en algunos casos?

Investigaciones recientes indican que las grasas altamente no saturadas, derivadas del pescado y conteniendo pocos o ningún ácido graso esencial, son capaces de producir una gran contracción de la concentración de lípidos en el plasma sanguíneo cuando las ingieren seres humanos normales y anormales. Esto parece indicar que el efecto reductor de lípidos del plasma que tienen las grasas no saturadas no está relacionado con la esencialidad de los ácidos grasos con varios enlaces no saturados que contienen, y que, por lo tanto, la hiperlipidemia no es una manifestación de insuficiencia de ácidos grasos esenciales.

Estudios realizados recientemente en nuestro laboratorio, entre los que estaban la cromatografía a través de ácido silícico para separar los lípidos del plasma y cromatografía a través de gas para las determinaciones cuantitativas de los ácidos grasos individuales que componen las diferentes fracciones de los lípidos del plasma, han demostrado que diversas fracciones de aceites de pescado tienen efectos distintos en la concentración de lípidos en el plasma. Específicamente, una fracción con un índice de yodo superior a 300 se ha demostrado que tiene un mayor efecto hipolipidémico. Los dos componentes principales de esta fracción son un ácido graso pentaenoico C^{20} y un ácido graso hexaenoico C^{22}. En las fracciones de los ésteres de colesterol de algunos pacientes a los que se administraba esta substancia, se observaron ácidos grasos altamente no saturados que no eran idénticos a los ácidos grasos de la alimentación. En algunos casos, parece haber habido un incremento del ácido araquidónico. Acidos grasos altamente no saturados también se han observado en ocasiones en algunas de las otras fracciones de los lípidos del plasma.

Los estudios han demostrado que las dietas mixtas que contienen grandes cantidades de pescado han arrojado recuentos de lípidos del plasma mucho menores que las que contienen cantidades aproximadamente iguales de proteína y grasa procedentes de la carne y de los productos lácteos. Estudios ulteriores empleando dietas constantes cuantitativamente se llevan a cabo actualmente con enfermos mantenidos en condiciones reguladas exactamente en la sala de casos de metabolismo.

Basándose en las observaciones citadas, parece desprenderse que la ingestión de pescado y derivados de éste está asociada con concentraciones bajas relativa y absolutamente con respecto a dietas que contienen poco o ningún pescado. También se sugiere que algunos de los ácidos grasos con varios enlaces no saturados "no esenciales", cuando los consumen personas adultas, se transforman en ácidos grasos con varios enlaces no saturados "esenciales".* Por lo tanto, no puede afirmarse categóricamente que el efecto de los ácidos grasos con varios enlaces no saturados en los lípidos del plasma no esté relacionado con la esencialidad. En vista de la relación entre la gran concentración de lípidos en el plasma y la predisposición a enfermedades coronarias del corazón y otras manifestaciones de aterosclerosis, existe una importantísima razón para determinar críticamente el lugar del pescado en la alimentación, con especial referencia a la posibilidad de lograr un efecto favorable en la producción o progresión de enfermedades vasculares degenerativas.

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* Desde la presentación de esta ponencia se ha demostrado que el ácido graso con un tiempo de retención aproximado del patrón C 20 : 4 *no* es ácido araquidónico

POLYUNSATURATED FATTY ACIDS IN FISH FAT, IN THE DIET AND IN THE BLOOD

by

OLAV NOTEVARP AND BJORG N. CYVIN

Results are reported which confirm that marine oils are particularly rich in their contents of higher polyunsaturated fatty acids (PUFA), pentaenoic and hexaenoic acids, while animal fats are low in their contents of PUFA, and vegetable oils in the higher PUFA. The relatively high contents of the higher PUFA in the liver and brain fats of cattle, horse and pigs, and in the liver oils of salmon, trout and whale, as well as in the phosphatides of cod and herring flesh, and of egg yolk, are suggested to indicate the important rôle of these acids in biological processes.

Data are presented which suggest that the content of total fatty acids (TFA), especially the sum of saturated and monoenoic acids (S + MFA) in blood serum may be a better index of atherosclerosis than cholesterol.

The failure of the human system to synthesize PUFA was confirmed. The contents of hexaenoic and pentaenoic acids in the serum lipids of healthy persons between 40 and 69 years of age were, respectively, 50 per cent and 80 per cent higher than in atherosclerotic patients. Both in atherosclerotic patients and in healthy persons, addition of 5 ml. of cod liver oil daily in the diet increased the contents of hexa- and pentaenoic acids in serum lipids while it lowered the contents of TFA, particularly S + MFA. Addition of soybean oil in the diet increased the content of dienoic acid in serum lipid but had no appreciable effects on the other PUFA.

Attention is drawn to the significant rôle of the hexa- and pentaenoic acids and consequently of seafoods in human nutrition which the results reported in the article indicate.

ACIDES GRAS POLYINSATURES DANS LA GRAISSE DE POISSON, DANS LE REGIME ALIMENTAIRE ET DANS LE SERUM DU SANG

On présente des résultats d'analyse qui confirment la richesse particulière des huiles d'origine marine en acides gras polyinsaturés (AGPI), notamment en acides penta- et hexa-énoïques, alors que les AGPI se présentent avec de basses teneurs dans les graisses animales ainsi que, pour les AGPI les plus élevés, dans les huiles végétales. La teneur relativement haute en AGPI élevés dans le foie et le cerveau des ruminants, du cheval et du porc, et dans les huiles de foie de saumon, de truite et de baleine, comme dans les phosphatides de la chair de morue et de hareng et dans le jaune d'oeuf, nous paraissent indiquer le rôle important de ces acides dans les processus biologiques.

On présente des données qui amènent à conclure que la teneur en acides gras totaux (AGT), notamment la somme de ces acides saturés et monoénoïques (AGS + M) dans le sérum du sang, peut être un indice d'athérosclérose meilleur que le cholestérol.

On a confirmé l'incapacité du système humain à effectuer la synthèse des AGPI. Les teneurs en acides hexa- et penta-énoïques dans les lipides du sérum de personnes saines de 40 à 69 ans se sont montrées respectivement de 50 et 80% plus élevées que chez des malades atteints d'athérosclérose. Chez ces derniers comme chez les personnes saines, l'addition de 5 ml. par jour d'huile de foie de morue dans le régime alimentaire accroît la teneur en acides hexa- et penta-énoïques dans les lipides du sérum alors qu'il abaisse la teneur en AGT et notamment en AGS + M. L'addition d'huile de soja dans le régime accroît la teneur en acide diénoïque dans les lipides du sérum, mais n'a pas d'effets marqués sur les autres AGPI.

On souligne le rôle significatif des acides hexa- et penta-énoïques et, par conséquent, celui des aliments d'origine marine en nutrition humaine, tels que les indiquent les résultats présentés dans cet article.

ACIDOS GRASOS CON VARIOS ENLACES NO SATURADOS EN LA GRASA DEL PESCADO, EN LA ALIMENTACION Y EN EL SUERO SANGUINEO

Se comunican resultados que confirman que en los aceites marinos abundan en particular los ácidos grasos con varios enlaces insaturados (AGEI), especialmente los penta y hexaenoicos, en tanto que en las grasas animales escasean todos y en los aceites vegetales, los más insaturados. El contenido relativamente elevado de los ácidos grasos más altamente insaturados en las grasas del hígado y cerebro de ganado vacuno, caballar y de cerda, en los aceites de hígado de salmón, trucha y ballena y en los fosfátidos de carne de bacalao y arenque y en la yema de huevos, parecen indicar que estos ácidos desempeñan un papel importante en los procesos biológicos.

Se dan datos que indican que el contenido de ácidos grasos totales, particularmente la suma de los saturados y los monoenoicos, en el suero sanguíneo puede ser un índice más exacto de aterosclerosis que el colesterol.

Se confirma la incapacidad del cuerpo humano de sintetizar los AGEI. En los lípidos del suero de personas sanas de 40 y 69 años, el contenido de ácidos hexa y pentaenoicos fueron, respectivamente, de un 50 y un 80% mayores que en enfermos de aterosclerosis. Tanto en el caso de éstos como en el de personas sanas, la adición diaria de 5 ml. de aceite de hígado de bacalao a la alimentación incrementó el contenido de ácidos hexa y pentaenoicos en los lípidos del suero y redujo el de ácidos grasos totales, particularmente de los saturados y monoenoicos; la adición de aceite de soja aumentaba el de ácido dienoico en los lípidos del suero, pero no tenía efectos sensibles en los otros AGEI.

Se pone de relieve el importante papel de los ácidos hexa y pentaenoicos y, por lo tanto, de los alimentos de origen marino en la nutrición humana, como lo indican los resultados mencionados en esta ponencia.

THE knowledge about fatty acid (FA) composition of fats has been extended very much in the last 10 years, especially by the introduction of spectrophotometric and gaschromatographic methods in fat research. The average content and distribution of polyunsaturated fatty acids (PUFA) in most of the common natural fats have been determined, and the characteristic differences in the PUFA patterns of fat from marine animals, land animals and plant products clearly demonstrated.

It has also been found that natural fats contain more fatty acids and isomers than formerly realized. Klenk and Steinbach (5), Stoffel and Ahrens (16), and others have shown that this especially applies to fish fats. The most abundant and characteristic PUFA of marine fats, however, are the C_{22}-hexaenoic, the C_{20}-pentaenoic and C_{18}-tetraenoic acids, together with a little C_{22}-pentaenoic and C_{20}-tetraenoic acids.

The total content of hexaenes, pentaenes, and tetraenes may be most accurately determined by their ultraviolet absorption after isomerization. In our work this method has been used for the determination of the PUFA group in fats from fish and fish products, milk, eggs, meats, different animal organs, cereals and other plant products, and in the blood serum from healthy men and from patients who have had one or more heart attacks. The intention has especially been to determine the distribution of the characteristic "marine" PUFA, the hexa- and pentaenoic acids, in foods, organs and blood.

This paper comprises fractions of our work, especially PUFA in fish fats, in the diet and in blood serum fats from healthy men and atherosclerotic patients. More detailed data for fish fats, is given in (6), and for blood serum fats in (7, 8, 9).

Material and methods

During the last 7–8 years samples have been collected of fish liver oils, all fish body oils and depot fats from fish and whales off the Norwegian coast and from the Antarctic. For the more important oils, e.g. cod-liver oil, herring, capelin and antarctic whale oils, the values shown are averages of 10 to more than 50 samples of each species and from different seasons. For milk and pig fats, the PUFA contents have also been determined in connection with feeding experiments (7, 11), and about 50 milk and 20 pig fat samples have been examined. Most of the other results represent averages of a number of samples, indicated in Tables I to IV, when the values have been determined in our laboratory.

The blood sera have mainly been obtained from the Central Hospital in Trondheim, through Dr. J. C. Lund, who suggested PUFA determinations in the blood because some relationship seems to exist between the PUFA content of the diet and the cholesterol content in the blood. All samples were taken in the morning, before any food had been consumed by the donor.

Some more determinations were done later on the effects of soybean oil and cod-liver oil in the diet on the PUFA content of blood serum fat.

The serum lipids were extracted by boiling absolute ethanol; the extract was then saponified and acidified, and the FA extracted with petrol ether. The acid content was determined by titration, the acid alkaliisomerized in micro scale, and the ultraviolet absorption determined in a Beckman recording spectrophotometer. PUFA in the other fats, oils and lipids were determined directly in the isolated fats or fatty acids on 30 mg. samples. These samples were isomerized in 10–11 g. 18 per cent KOH in ethylene glycol for 8 min. by 180°C. For blood serum fat about 0·5–1·5 mg. of FA and 0·5 ml. KOH-solution have been used.

For the calculation of the contents, constants determined in our laboratory by O. Höyland (4) on pure C_{22}-hexa-, C_{20}- and C_{22}-penta- and C_{18} and C_{20}-tetraenoic acids, prepared by himself, and of pure linolenic and linoleic acids, have been used:

K-values ($=\frac{1}{10}$ E 10 g./l·1 cm.)

Wave lengths, Å:	3730	3460	3150	2690	2340
Hexaene, C_{22}	43	55	61	50	55
Pentaenes, C_{20}–C_{22} (ab. 0·9–0·1)	0	58	69	57	57·5
Tetraenes, C_{18}–C_{20} (ab. 0·9–0·1)	0	0	75	51	33
Trienes, C_{18}	0	0	0	89	48
Dienes, C_{18}	0	0	0	0	94

Höyland has also made many of the PUFA determinations referred to in this paper.

Results

(a) **Meat, milk, egg, and margarine fats.** Table I shows some of the mean values. The ruminants depot fats and

TABLE I

Average contents of fatty acid groups in meat, milk, egg and margarine fat

		% of total fatty acids						
Source	*n*	*Saturated*	*Monoenoic*	*Dienoic*	*Trienoic*	*Tetraenoic*	*Pentaenoic*	*Hexaenoic*
Cattle	(L)	50	47	2	0	0	0	0
Sheep	(L)	58	38	3	1	0	0	0
Horse	(L)	33	33	7	14	6–8?	?	?
Pig	20	40	48	9	1·5	0·4	0·1–0·2	0·1–0·2
Cows milk	52	69	26	2·5 (1·4)	0·8	0·2	0·25	0·1
Human milk	10	48	43	5·1 (4·4)	0·8	0·4	0·5	0·8
Horse milk [1]	4	34	32	11	16·7	0·3	0·08	0·06
Eggs	2	27	62	8	0·2	0·7	0·2	0·9
Margarine, ordinary	3	45	50	4–8	0·5	0	0	0
Margarine, vegetable	3	55	35	9–10	1	0	0	0

n: Number of samples examined. (L): Figures from literature (2) ? Indicates that values are not available or uncertain. Bracketed values for milk fats indicate linoleic acid. The differences are conjugated dienoic acids.

[1] Pasture fed.

TABLE II

Average contents of fatty acid groups in fish, whale and fish products

		% of total fatty acids						
Source	*n*	*Saturated*	*Monoenoic*	*Dienoic*	*Trienoic*	*Tetraenoic*	*Pentaenoic*	*Hexaenoic*
Herring, body	>25	25	55	3·5	2	3·5	9	7
Herring, flesh	3	27	52	4·0	1·5	3·5	7	5
Mackerel, flesh	1	20	54	5·5	3	5	7	5·5
Sprat, body	1	13	54	4·5	2	4·5	10	12
Capelin, body	>20	25	60	2·5	1	1·5	5·5	4·5
Salmon, sea, flesh	3	30	40	2·5	1	2·5	8	16
Whale, antarctic, blubber [1]	>50	25	53	3·5	1·5	2	10	5·5
Brit, antarctic	1	37	27·5	2·5	—	3	19·5	10
Cod, liver	>10	17	49	3·5	1·5	2·5	12	14
Saith, liver	>10	18	51	3	1·5	3	12	11
Cod roe	1	21	35	2	0·5	3	13	25
Salmon, roe	2	21	42	2	0	1·7	16	17
Herring, milt	3	(30)	(10)	4	0·5	3	15	35

[1] Mean values for blue and fin whales, because their mean fatty acids distribution has not been found significantly different and seems to depend mainly on their feed and condition.

( ) Indicate that figures are approximate.

TABLE III

Average contents of fatty acid groups in fatty acids from different organs and phosphatides

		% of total fatty acids						
Source	*n*	*Saturated*	*Monoenoic*	*Dienoic*	*Trienoic*	*Tetraenoic*	*Pentaenoic*	*Hexaenoic*
Salmon, sea, liver	2	12	55	4	2·5	5·5	12	9·5
Trout, fresh water, liver	1	10	69	6·4	4·1	2·9	3·3	4·4
Whale, liver	4	40	28	4	2	6	14	6
Pig, liver	5	25	40	12	4·5	8	6	5
Pig, brain	6	64	17	4	4·5	5	1	5
Whale, brain	4	44	42	3	3	3	1·5	3·2
Cattle, brain	1	(35)	(10)	8	10	9	3	14·5
Horse, brain	1	(65)	(5)	6	6	7	1	9·5
Phosphatide f.a. from:								
Cod flesh	1			4·5	0·5	7	21	27
Herring flesh	1			3·4	0·7	1·5	14	33
Egg yolk	2			9	1	3	0·8	4
Blood serum (healthy men)	>50	35	32	23	1·5	3	2·8	2·5

( ) Indicates that figures are approximate.

TABLE IV

Average contents of fatty acid groups in fatty acids from vegetables

		% of total fatty acids						
Source	*n*	*Saturated*	*Monoenoic*	*Dienoic*	*Trienoic*	*Tetraenoic*	*Pentaenoic*	*Hexaenoic*
Wheat	6	20	21	50	6	0·3	0·3	0
Rye	4	18	23	44	6	0·5	0·5	0
Barley	4	20	25	48	5	0·5	0·4	0
Oats	3	15	39	38	2	0·5	0·2	0
Corn	(L)	12	30	55	1	0	0	0
Soybeans	5	14	26	52	7	0	0	0
Peanut	(L)	19	50	30	0	0	0	0
Coconut	(L)	91	7	1	0	0	0	0
Peas, green	1	22·5	14	52	11	0·1	0	0
Spinach	1	14	15	25	44	1·1	0·3	0
Lettuce, green	1	8	38	54	0	0	0	0

(L): Figures from literature (2).

milk fats contain very little PUFA; pork fat, human milk and egg fat 5–10 per cent linolenic acid and a little of the PUFA with higher degree of unsaturation. Horse and horse milk fats are characterized by their high trienoic acid contents.

(b) **Fats from fish, whale and fish products** (Table II). All marine oils and fats contain appreciable amounts of hexaenoic and pentaenoic acids. Salmon flesh fat has the highest percentage of the fish flesh fats shown, whilst liver oils ordinarily contain 10–15 per cent hexaenoic and 10–13 per cent pentaenoic acids. Fatty acids from herring milt have been found to contain up to 40, and cod roe up to 30 per cent hexaenoic acid. The fat of brit, the important food for the antarctic whales, was found to contain about twice as much pentaenoic and hexaenoic acid as the ordinary antarctic whale oil.

(c) **Different organs and phosphatides.** PUFA values for fatty acids from different organs and phosphatides are shown in Table III. All of the organs contain appreciable amounts of hexaenoic, the livers contain perceptible quantities of pentaenoic acids also. The brain fatty acids show low values for pentaenes, but higher values for tetra-, tri- and dienes Phosphatide FA from cod and herring flesh show high contents of hexa- and pentaenoic acids, which also are present in appreciable quantities in blood sera from healthy persons. In egg yolk phosphatide, di-, tetra- and hexaenoic acids are the most predominating PUFA.

The relative high percentages of the *most unsaturated PUFA*, the "marine" hexa- and pentaenoic acids, in important animal organs and in phosphatides indicate that these acids may play an important rôle in the life processes.

(d) **Vegetable fats.** For comparison, the PUFA contents of some vegetable fats are given in Table IV. The values for corn, peanut and coconut fats are taken from relevant documents; the others are results obtained on Norwegian products (except soybeans).

As commonly known, the PUFA of seed fats consist mainly of linoleic and some linolenic acids. In green vegetables and grass fat, linolenic acid may dominate. Hexaenoic acid has not been found in vegetable fats, but small amounts of penta- and tetraenoic acids are shown to be present in grain and spinach.

The great difference between the PUFA composition of marine oils and vegetable oils is obvious. To illustrate this fact clearly, Fig. 1 shows the PUFA contents of some typical vegetable, animal and marine fats.

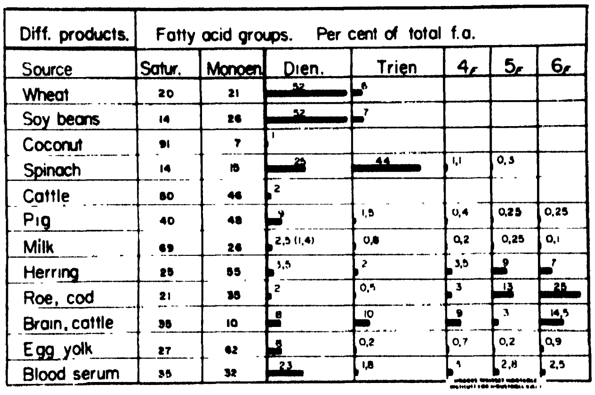

Fig. 1. This shows the PUFA contents of some typical fats.

Blood serum lipids

Table V shows average contents of cholesterol, total fatty acids (TFA), PUFA and saturated + monenoic acids (S + MFA) in blood sera, and percentages of the various PUFA-groups in the TFA of blood sera from healthy Norwegian men in five age groups (20–29 to 60–69 years), and for patients (men who have had heart attacks) in age groups 40–59 and 60–72 years.

For healthy men the contents of cholesterol, TFA and S + MFA are found to increase with age up to 50–60 years. The increase in S + MFA is about 33 per cent, in cholesterol 20 per cent. The average cholesterol content for the patients was only about 5 per cent higher than the average content for healthy men in the same age groups, whilst the average S + MFA content was about 30 per cent, the TFA-content about 21 per cent, higher for the patients.

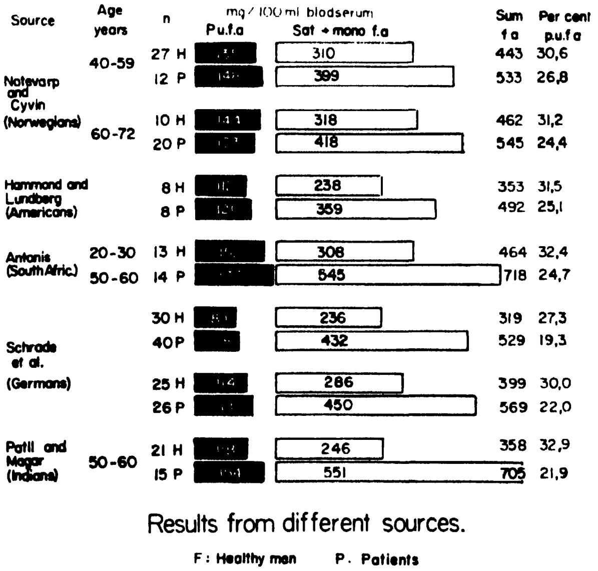

Fig. 2. Shows in diagrammatic form the results outlined in Table VI (see text).

Even higher differences in the contents of S + MFA and TFA for atherosclerotic and healthy persons are shown by results published by other investigators, e.g. Hammond and Lundberg (3), Antonis (1) Schrade and co-workers (13, 14, 15) and Patil and Magar (12). Values calculated from their results together with our own are shown in Table VI and illustrated in Fig. 2. The differences in TFA and in S + MFA indicate the TFA content, and especially the S + MFA content, in

TABLE V

Average PUFA and cholesterol content in human blood serum lipids

		mg./100 ml. serum				% PUFA in total f.a.					
Number	*Age gr. years*	*Cholesterol*	*Sat. + monoenoic f.a.*	*PUFA*	*Total f.a.*	*Dienoic*	*Trienoic*	*Tetraenoic*	*Pentaenoic*	*Hexaenoic*	*Total*
Healthy men:											
22	20–29	217	244	125	369	24·8	1·8	3·0	2·4	2·4	33·8
37	30–39	232	276	130	406	23·3	1·8	2·7	2·2	2·2	32·2
16	40–49	263	297	135	432	22·5	1·6	2·4	2·3	2·4	31·2
11	50–59	252	324	136	460	18·9	1·9	2·8	3·4	2·7	29·7
10	60–69	273	318	144	462	20·6	1·6	2·5	3·5	3·0	31·2
Patients:											
12	40–59	289	399	148	547	19·0	1·8	2·3	1·9	2·0	27·0
20	60–72	269	417	134	551	17·4	1·5	2·0	1·6	1·8	24·35

TABLE VI

Polyunsaturated fatty acid content of blood serum fat from healthy men and atherosclerotic patients calculated according to results from different investigators

		Persons tested			Fatty acids in mg./100 ml. blood serum			
Source	*Nationality*	*Number*	*Age Years*	*H or P*	*Total*	*PUFA*	*Sat. + monoenoic*	*% PUFA in total f.a.*
Hammond and Lundberg (1955)	U.S.	8		H	353	112	238	31·5
	cit.	8		P	492	121	359	25·1
Antonis (1958) . . .	South	13	20–30	H	464	152	308	32·4
	Africans	14	50–60	P	718	173	545	24·7
Schrade *et al.* (1959, 1) . .	Germans	30		H	319	89	236	27·3
		40		P	529	98	432	19·3
(1959, 2) (gaschr.) . . .	Germans	25		H	399	114	286	30·0
		26		P	569	126	450	22·0
(1960)	Germans	20	51–60	H	364	98	266	26·9
		43	51–60	P	524	103	421	19·6
Notevarp (1960) . . .	Norwegians	27	40–59	H	445	135	310	30·6
		12	40–59	P	547	148	399	26·8
	Norwegians	10	60–72	H	462	144	318	31·2
		20	60–72	P	551	134	417	24·4
Patil and Magar (1960) . .	Indians	21	50–60	H	358	118	246	32·9
		15	50–60	P	705	154	551	21·9

H : Healthy; P : Patients.

blood serum to be more valuable for the diagnosis of atherosclerosis than the cholesterol content.

Fish oil and blood serum fatty acids

Effects on the serum lipids of the addition of cod-liver oil and of soybean oil to the diet of healthy men and atherosclerotic patients are shown in Table VII. According to Table V, the average content found for men between 40 and 69 years of hexaenoic acids is 50 per cent, of pentaenoic 80 per cent, higher for the healthy men than for the patients.

These results may indicate some effect of these acids in the prevention of atherosclerosis. Table VII shows how addition of only 5 ml. cod-liver oil daily increased the contents of hexa- and pentaenoic acids in the serum fat. Addition of soybean oil increased the content of dienoic acid, but did not seem to affect appreciably the content of other PUFA in the blood serum fat. The results may indicate that the human organism has no, or only a slight, ability to transform linoleic acid to higher unsaturated FA, and that hexa- and pentaenoic acids must be supplied through the diet if the contents of these acids in blood serum fat is to be increased substantially.

The effect of cod-liver oil on the content of TFA and of S+MFA in blood serum may also be seen from Table VII. Both in healthy men and in patients the TFA contents and especially the S + MFA contents have been substantially lowered by the additions of cod-liver oil to the diet. The results may illustrate the importance in the diet of seafoods and marine fats, our best and most abundant sources of hexa- and pentaenoic acids.

TABLE VII

Effect of unsaturated oils in the diet on PUFA in blood serum fat

Initials and Age	*Diet and Supplements*	*mg./100 ml. serum*			*% PUFA in total f.a.*					
		Cholesterol	*Total f.a.*	*S + M f.a.*	*Hexaenoic*	*Pentaenoic*	*Tetraenoic*	*Trienoic*	*Dienoic*	*Total PUFA*
Healthy men:										
H.E. 24	Ordinary diet, no oil added	161	358	227	2·6	2·2	3·8	2·1	26·0	36·7
	Ordinary diet + 5 ml. cod liver oil/daily for 3 months	229	330	208	4·7	3·7	2·9	1·8	23·9	37·0
S.L. 25	Ordinary diet, no oil added	226	439	293	2·3	2·1	3·8	1·6	23·4	33·2
	Ordinary diet + 10 ml. cod liver oil/daily for 3 months	259	360	195	5·8	8·6	4·2	1·3	26·1	46·0
	No cod liver oil for 14 days	288	347	214	4·7	6·6	3·0	0·3	23·7	38·3
O.N. 60	Plenty fish, 3–5 ml. cod liver oil/daily	249	467	322	5·4	8·3	3·8	1·0	12·7	31·2
	Plenty fish, 3–5 ml. cod liver oil/daily + 20 ml. soybean oil/daily for 6 days	237	497	301	3·7	6·7	3·9	1·9	23·2	39·4
	Plenty fish, 3–5 ml. cod liver oil/daily + 5–7 ml. soybean/daily for 6 months	280	467	271	5·4	8·2	3·8	1·3	23·4	42·1
Patients:										
W.H. 42	Some soybean oil daily	276	705	501	1·9	1·1	2·5	2·3	22·0	29·0
	Some soybean oil + 5–7 ml. cod liver oil/daily for 6 months	267	523	350	4·9	5·7	2·7	1·2	18·6	33·0
A.S. 50	5–7 ml. cod liver oil/daily	262	580	429	4·6	4·3	2·1	1·0	14·1	26·1
	10 ml. soybean oil/daily for 2 months	258	486	335	2·3	2·2	2·5	0·9	23·2	31·2
	10 ml. soybean oil + 5 ml. cod liver oil/daily for 2 months	248	422	252	3·5	2·9	2·7	2·3	28·9	40·3
A.F.	Same day as heart attack	247	516	415	0·8	0·7	1·9	2·4	13·8	19·6
	Ordinary hospital diet for 19 days	193	322	255	1·1	1·2	2·4	2·1	13·9	20·7
	Ordinary hospital diet + 5 ml. cod liver oil + 10 ml. soybean oil daily for 7 days	223	414	302	1·5	1·8	2·5	2·3	19·3	27·4
	Ordinary hospital diet + 5 ml. cod liver oil + 10 ml. soybean oil daily for + 7 days	—	396	263	2·0	2·7	2·6	2·3	24·0	33·5

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USE OF FISH IN THE CONTROL OF HYPERCHOLESTEREMIA AND OBESITY

by

C. M. HARLOW and A. R. MORTON

A great deal of attention is being focused on hypercholesteremia as an important factor in the genesis of atherosclerosis; and many regimens, both dietary and drug, are being advocated in an attempt to normalize cholesterol levels.

Fats have been the most predominant food substance implicated in the supposed cause of a raised serum cholesterol; however, there are many who believe that carbohydrates and even proteins play an important part in the percentage of cholesterol found in the blood.

Several years ago we formulated the idea of placing supposedly healthy groups of men on well-balanced diets, which could be easily adjusted to varying amounts of different fats, protein and carbohydrate. We followed the N.R.C. Food and Research Board's (Canadian Food Rules are quite similar) recommended allowances as a guide in prescribing their daily food intake.

Most of these men were totally unaware of our National or Canadian Food Rules. The first step was to familiarize the selected men with their use, and then to assist in their application. This was quite simply done by advocating a daily caloric intake of 1800, 2000, 2400 or 2600 calories depending upon his present weight compared to what his ideal should be. The daily variety was further simplified by the use of the Exchange System of measuring advocated by a joint committee of the American Diabetes and Dietetic Associations.

For a year we have followed the serum cholesterol and weight level of 4 groups of 167 healthy Halifax City policemen aged 19–60.

The men whom we treated in each experimental group consumed fish 3 to 9 times a week. Vegetable oils used in salads and cooking also helped adjust the fat content of their diet into the 30–35 per cent range; the proportion of unsaturated to saturated fatty acid approximated a 3 : 1 ratio.

The average cholesterol and weight levels of 33 men (from age group 20–29) were 195 mg. per cent and 193 lbs.; after 1 year of treatment their average was 183 mg. per cent and 192 lbs. Nineteen men (aged 30–39) had levels averaging 265 mg. per cent and 211 lbs; they also dropped to an average of 223 mg. per cent and 201 lbs. Twenty-six policemen (aged 40–49) averaged 243 mg. per cent and 208 lbs. whilst 12 months later their average was 209 mg. per cent and 201 lbs. The last group of 8 men (aged 50–59) had averages of 232 mg. per cent and 207 lbs., which had dropped to 215 mg. per cent and 200 lbs. 1 year later.

The mean cholesterol and weight levels of 33 controls were 219 mg. per cent and 192 lbs. at the beginning, and 231 mg. per cent and 195 lbs. at the end of the study.

We used the Abel method for cholesterol determinations.

It has been shown that a motivated group can assist the correction of obesity and hypercholesteremia by a well-balanced diet in which fish and vegetable oils play an important part.

It is intended to keep these policemen under observation for a number of years, to try to correlate atherosclerosis with the aforementioned changes.

L'UTILISATION DU POISSON DANS LE CONTROLE DE L'HYPERCHOLESTEREMIE ET DE L'OBESITE

On porte actuellement une grande attention sur l'hypercholestérémie comme facteur important de la genèse de l'athérosclérose; et bien des régimes, à la fois diététiques et pharmaceutiques, sont proposés pour tenter de normaliser les taux de cholestérol.

Les graisses ont été les substances alimentaires prédominantes les plus invoquées comme cause supposée d'une augmentation du cholestérol du sang; cependant, beaucoup pensent que les glucides, et même les protéines, jouent un rôle important dans le taux de cholestérol trouvé dans le sang.

Il y a quelques années, nous avons projeté de faire suivre à des groupes d'hommes, considérés en bonne santé, des régimes bien équilibrés qui pouvaient être facilement réglés sur des quantités variables de graisses, protéines et glucides divers. Nous avons suivi comme guide, pour prescrire leur alimentation quotidienne, les rations recommandées par le N.R.C. Food and Research Board (les "Canadian Food Rules", règles alimentaires canadiennes, sont tout à fait semblables).

La plupart de ces hommes ignoraient complètement nos règles nationales ou les règles canadiennes d'alimentation. La première étape a consisté à familiariser ces collaborateurs à leur usage et, ensuite, à les assister dans leur application. Cela a été réalisé très simplement en leur proposant une consommation quotidienne en calories de 1800, 2000, 2400 et 2600 calories, selon la comparaison qu'on pouvait faire entre leur poids actuel et le poids idéal. La variété alimentaire quotidienne a été simplifiée par la suite en utilisant pour les mesures le "système d'échange" (Exchange System) proposé par un comité mixte des associations américaines de diabète et de diététique.

Durant une année, nous avons suivi le cholestérol du sang et le poids de 167 policiers de la ville d'Halifax, tous en bonne santé, âgés de 19 à 60 ans et répartis en 4 groupes.

Dans chaque groupe expérimental, les hommes traités consommaient du poisson 3 à 9 fois par semaine. Les huiles végétales utilisées pour les salades et la cuisine servaient également à régler la teneur en graisses de leurs régimes à un niveau intermédiaire entre 30 et 35%; le rapport des acides gras insaturés aux acides gras saturés était de 3/1.

Les moyennes de cholestérol et de poids de 33 hommes, du groupe d'âge 20–29 ans, étaient de 195 mg./100 g. et 193 lb. (87,54 kg); après un an, ces moyennes étaient de 183 mg./100 g. et de 192 lb. (87,09 kg.). Pour 19 hommes, de 30–39 ans, on avait respectivement 265 mg./100 g. et 211 lb. (95,71 kg.), et ces chiffres tombaient également après un an à des moyennes de 223 mg./100 g. et 201 lb. (91,17 kg.). Pour 26 policiers de 40–49 ans, les moyennes étaient de 243 mg./100 g. et 208 lb. (94,35 kg.); après un an, elles étaient devenues 209 mg./100 g. et. 201 lb. Pour le dernier groupe de 8 hommes, de 50–59 ans, on passait des moyennes de 232 mg./100 g. et 207 lb. (93,90 kg.) à 215 mg./100 g. et 200 lb. (90,72 kg.) un an plus tard.

Les moyennes du cholestérol et du poids du groupe-témoin de 33 hommes étaient de 219 mg./100 g. et 192 lb. (87,09 kg.) au début de l'étude et de 231 mg./100 g. et 195 lb. (88,45 kg.) à la fin.

Le cholestérol était déterminé par la méthode Abel.

Ces résultats montrent qu'un groupe, dont on a stimulé l'intérêt, peut concourir à la correction de son obésité et de son hypercholestérémie à l'aide d'un régime bien équilibré, dans lequel le poisson et les huiles végétales jouent une part importante.

Nous avons l'intention d'observe régulièrement ces policiers pendant quelques d'années pour étudier et mettre en corrélation l'athérosclérose avec les changements précités.

EMPLEO DEL PESCADO EN LA LUCHA CONTRA LA HIPERCOLESTEREMIA Y LA OBESIDAD

Se presta actualmente mucha atención a la hipercolesteremia como factor importante de la génesis de la aterosclerosis; y muchos regímenes dietéticos y farmacéuticos se proponen para tratar de normalizar las concentraciones de colesterol.

Las grasas han sido las substancias alimentarias predominantes más invocadas como causa supuesta de un aumento del colesterol de la sangre; sin embargo, hay muchos que creen que los carbohidratos (e incluso las proteínas) desempeñan un papel importante en el tenor de colesterol que se encuentra en la sangre.

Hace varios años propusimos la idea de que grupos de hombres considerados de buena salud siguieran regímenes bien equilibrados que podrían regularse fácilmente para incluir cantidades diferentes de grasas, proteínas y carbohidratos distintos. Como guía para prescribir su consumo diario de alimento, seguimos las raciones recomendadas por la N.R.C. Food and Research Board (las disposiciones alimentarias canadienses son análogas).

La mayor parte de estos hombres desconocía totalmente nuestras disposiciones nacionales o las canadienses relativas a la alimentación. El primer paso consistió en familiarizarlos con su empleo y, a continuación, ayudarles en su aplicación. Esto se realizó simplemente al proponer un consumo diario de 1.800, 2.000, 2.400 y 2.600 calorías según la comparación de su peso actual con su peso ideal. La variedad cotidiana de alimentos se simplificó todavía más empleando el sistema de intercambio de medidas propuesto por un comité mixto de las asociaciones americanas de diabetes y dietética.

Durante un año hemos examinado el colesterol de la sangre y el peso de 167 policías de la ciudad de Halifax, de buena salud, de 19 a 60 años de edad, distribuidos en 4 grupos.

En cada grupo experimental, los hombres sometidos a tratamiento consumían pescado de 3 a 9 veces por semana. Los aceites vegetales empleados en las ensaladas y en la cocina también contribuían a ajustar el contenido de grasa de sus regímenes a un nivel intermedio entre 30 y 35%; la proporción de ácidos grasos insaturados y saturados era de 3 a 1.

Los promedios del colesterol y el peso de 33 hombres del grupo de edad de 20 a 29 años eran de 195 mg. por 100 g. y 193 libras (87,54 Kg.); después de un año, estos promedios eran de 183 mg. por 100 g. y de 192 libras (87,09 Kg.). Diecinueve hombres de 30 a 39 años de edad tenían promedios de 265 mg. por 100 g. y de 211 libras (95,71 Kg.), cifras que también se redujeron a un promedio de 223 mg. por 100 g. y de 201 libras (91,17 Kg.). Veintiseis policías de 40 a 49 años dieron un promedio de 243 mg. por 100 g. y 208 libras (94,35 Kg.), que 12 meses después se habían reducido a 209 mg. por 100 g. y 201 libras. El último grupo de 8 hombres de 50 a 59 años tenía un peso medio de 207 libras (93,90 Kg.) y 232 mg. por 100 g., que un año más tarde se habían contraído a 200 libras (90,72 Kg.) y 215 mg. por 100 g.

Los promedios de colesterol y de peso de un grupo testigo de 33 hombres eran de 219 mg. por 100 g. y 192 libras (87,09 Kg.) al comienzo del estudio y de 231 mg. por 100 g. y 195 libras (88,45 Kg.) al terminar.

El colesterol se determinó por el método Abel.

Se ha demostrado que un grupo estimulado por el interés puede contribuir a la corrección de su obesidad e hipercolesteremia con ayuda de un régimen bien equilibrado en el que el pescado y los aceites vegetales desempeñen un papel importante.

Se intenta seguir estudiando a estos policías durante un número de años para tratar de relacionar la aterosclerosis con los cambios precitados.

NUTRITIVE VALUES OF MARINE ANIMAL OILS

by

TAKASHI KANEDA

(1) *Nutritive value of polyunsaturated fatty acids in marine animal oils*

The author carried out systematic research of lipids of fish and found the following points:

Although the nutritive value of fish oils usually had been evaluated at a low level, fish oils in their pure state show a high nutritive value; it is only autoxidized fish oil that is nutritiously inferior. In particular, polyunsaturated fatty acids in fish oils, which so far had been believed to be toxic, are as good as oleic acid for a caloric source if they are maintained unchanged. Therefore, the toxicity should not be attributed to the polyunsaturated fatty acids themselves, but to peroxide which results from their autoxidation.

(2) *Nutritive value and toxicity of oils of salt-dried fishes and fish meal*

The nutritive value of oils of salt-dried fishes is influenced by the degree of autoxidation; and with oils of high iodine value the nutritive value becomes lower when the oil is autoxidized.

The nutritive value of oil which was separated from sardine meal was much inferior to that of soybean oil, and it appeared to have practically no value as food. This result indicates that, although fish meal oil has autoxidized to too great an extent to exhibit a marked toxic effect, it has lost much of its nutritive value.

(3) *The effect of cuttle-fish liver oil on cholesterol metabolism in the rat*

Dr. Alfin-Slater (University of California) and the author found the cuttle-fish liver oil can reduce the cholesterol content in plasma of rats; however, the effect of this oil on liver and adrenal cholesterol is less than that of essential fatty acids.

The effects of fucosterol to plasma or liver cholesterol of rats

The author separated fucosterol from *Fucus evanescens* and *Pelvetia wrightii*, and carried out feeding experiments with rats, using fucosterol and cholesterol. The result was that fucosterol reduced liver cholesterol.

VALEUR NUTRITIVE DES HUILES D'ANIMAUX MARINS

(1) *Valeur nutritive des acides gras polyinsaturés dans les huiles d'animaux marins*

L'auteur a effectué une recherche systématique sur les lipides du poisson, qui l'a conduit aux résultats suivants:

Bien que la valeur nutritive des huiles de poisson ait été habituellement évaluée à un niveau bas, les huiles de poisson dans leur. état pur montrent une haute valeur nutritive; seule l'huile de poisson auto-oxydée est d'une qualité nutritive inférieure. En particulier, les acides gras polyinsaturés dans les huiles de poisson, qui ont été considérés jusqu'ici comme toxiques, sont aussi bons que l'acide oléique comme source de calories dans la mesure où ils sont maintenus sans altération. De ce fait, la toxicité ne devrait pas être attribuée aux acides gras polyinsaturés eux-mêmes, mais aux peroxydes qui résultent de leur auto-oxydation.

(2) *Valeur nutritive et toxicité des huiles de poisson séché salé et de farine de poisson*

La valeur nutritive des huiles de poisson salé séché est influencée par le degré d'auto-oxydation; avec des huiles de haut indice d'iode, la valeur nutritive diminue quand l'huile est auto-oxydée.

L'huile séparée de la farine de sardine s'est montrée d'une valeur nutritive bien inférieure à celle de l'huile de soja et même sans valeur pratique comme aliment. Ce résultat montre que, bien que la farine de poisson se soit auto-oxydée dans une mesure trop grande pour présenter un effet toxique marqué, elle a perdu la plupart de sa valeur nutritive.

(3) *L'effet de l'huile de foie de seiche sur le métabolisme du cholestérol chez le rat*

Le Dr. Alfin-Slater (Université de Californie) et l'auteur ont trouvé que l'huile de foie de seiche pouvait réduire la teneur en cholestéro du plasma chez les rats; cependant, l'effet de cette huile sur le cholestérol du foie et des surrénales est moindre que celui des acides gras esentiels.

Les effets du fucostérol sur le cholestérol du plasma ou du foie chez les rats

L'auteur a séparé du fucostérol de *Fucus evanescens* et *Pelvetia wrightii*, et il a effectué des expériences d'alimentation avec des rats, utilisant le fucostérol et le cholestérol. Le résultat de ces expériences est que le fucostérol réduit le taux de cholestérol du foie.

VALOR NUTRITIVO DE LOS ACEITES DE ANIMALES MARINOS

(1) *Valor nutritivo de los ácidos grasos con varios enlaces no saturados de aceites de animales marinos*

El autor realizó una investigación sistemática de los lípidos del pescado y llegó a las siguientes conclusiones:

Aunque el valor nutritivo de los aceites de pescado se habían evaluado usualmente a concentraciones bajas, estos aceites, cuando son puros, tienen un gran valor nutritivo; son solamente los autooxidados los que resultan inferiores desde el punto de vista de la nutrición. Los ácidos grasos con varios enlaces no saturados, considerados hasta ahora como tóxicos, son tan buenos como el ácido oleico como fuente de calorías si se mantienen inalterados; por lo tanto, la toxicidad no deberá atribuirse a los ácidos grasos con varios enlaces no saturados sino al peróxido que produce su autooxidación.

(2) *Valor nutritivo y toxicidad de los aceites de pescado curado con sal y harina de pescado*

En el valor nutritivo de los aceites de pescado curado con sal influye el grado de autooxidación; y en los aceites de elevado índice de yodo, el valor nutritivo se reduce cuando se autooxidan.

El valor nutritivo del aceite extraído de harina de sardinas era muy inferior al del aceite de soja y prácticamente parecía no tener valor como alimento. Este resultado indica que, aunque el aceite de harina de pescado se ha autooxidado demasiado para tener un marcado efecto tóxico, ha perdido mucho de su valor nutritivo.

(3) *Efecto del aceite de hígado de calamar en el metabolismo del colesterol de la rata*

El Dr. Alfin-Slater (Universidad de California) y el autor observaron que el aceite de hígado de calamar puede reducir el contenido de colesterol en el plasma de las ratas, aunque el efecto de este aceite en el colesterol del hígado y de la cápsula suprarrenal es inferior al de los ácidos grasos esenciales.

Los efectos del fucosterol en el colesterol del plasma o hígado de las ratas

El autor extrajo fucosterol de *Fucus evanescens* y *Pelvetia wrightii* y realizó experimentos de alimentación con ratas, empleando fucosterol y colesterol. El resultado fue que el fucosterol redujo el colesterol del hígado.

THE NUTRITIVE VALUE OF SARDINES

by

S. A. MILLER, H. A. DYMSZA, and S. A. GOLDBLITH

A series of studies has been made to determine the nutritive value of sardines (*Clupea harengus*, Atlantic) in terms of the nutrient pattern, availability of protein and fat, and its influence on serum cholesterol and vascular sudanophilia. In addition, the influence of two different processing methods (namely, steam-cooking and frying) on these nutrients was also studied.

(1) *Nutrient Characterization*

Samples selected at random from the 1956 pack of five different processors, located in the state of Maine, were analysed for the following nutrients: protein, amino acids, fat, moisture, ash, crude fiber, iron, chloride, fluorine, calcium, phosphate, thiamine, riboflavin, pyridoxine and niacin. In addition, the sardine oil and packing liquid were characterized in terms of iodine number, free fatty acids, refractive index, cholesterol and unsaturated fatty acid composition.

The results of this study indicate that sardines are a good source of a number of nutrients, including protein (23 per cent), calcium (470 mg./100 g.), thiamine (0·133 mg./100 g.), fluorine (4·50 mg./100 g.), and pyridoxine (0·133 mg./100 g.). In addition, the pattern of amino acids is good, with lysine in particular being present in high concentrations (9·02 per cent of the drained sardine protein). Furthermore, the fatty acid composition of the sardine oil tended to be high in unsaturated fatty acids, particularly the pentaenoic acids. Some evidence for an exchange between the packing liquid and the fish was also found.

(2) *Availability and utilization of sardine protein and fat*

Young, male, Sprague-Dawley rats were fed agar-gel diets *ad libitum*, in which sardines, either steam-processed or fried, or casein and lard supplied all of the protein and fat. All three rations supplied approximately 10 per cent protein and 6 per cent fat, and were fed for 5 months.

No significant differences in growth, food and protein-efficiency or carcass-composition were observed between rats fed the casein-lard control ration and animals fed either steam-cooked or fried sardines as a source of protein and fat. Furthermore, histopathological examination of the sardine-fed animals revealed no evidence of any pathological lesion in any system examined, including those of the circulatory system.

(3) *Influence on serum cholesterol and vascular sudanophilia*

Young male rats were fed, *ad libitum*, agar-gel diets containing 0·5 per cent cholesterol and 0·25 per cent cholic acid. In one ration, casein and lard were the sources of protein and fat, while in the other ration whole, ground, drained sardines replaced casein and lard. Both rations contained approximately 12 per cent protein and 6 per cent fat. Blood samples were taken periodically for cholesterol analysis. Ten animals from each group were autopsied at 55 weeks. Hearts and aortas were then stained with Sudan IV, and examined for the extent of sudanophilia.

Animals fed the casein-lard rations developed, within one week, a severe hypercholesteremia that was maintained throughout the test. In contrast, animals fed the sardine ration did not develop a severe hypercholesteremia for the entire test period. A third group, fed the casein-lard diet for 7 weeks and then the sardine diets for the remainder of the test, also developed a severe hypercholesteremia during the first 7 weeks. Upon being changed to the sardine diets, serum cholesterol levels fell rapidly, approximately to the levels of the animals fed sardines from the beginning of the test. Measurements of vascular sudanophilia indicated that the animals fed the casein-lard diets developed a more marked sudanophilia than did either of the two groups fed sardines. However, the animals that were first stressed with the casein-lard diets prior to being fed sardines showed the lowest amount of sudanophilia.

(4) *Conclusions*

The results of this study indicated that sardines, a relatively inexpensive food material, can be considered a good source of a number of essential nutrients, particularly protein and unsaturated fatty acids. Furthermore, the data also demonstrate that, in the cholesterol-cholic acid stressed rat, sardine diets can not only prevent a rise in serum cholesterol, but can also reduce the serum cholesterol level of hypercholesteremic rats. Moreover, there is an indication that sardine diets can inhibit to some extent the accumulation of lipoidal material in the aortas and hearts of these animals.

LA VALEUR NUTRITIVE DES SARDINES

Une série d'études a été effectuée pour définir la valeur nutritive des sardines (*Clupea harengus*, Atlantic) en fonction de la distribution de leurs éléments nutritifs, de leur disponibilité en protéines et en graisses, et de leurs influences sur le cholestérol du sang et sur la soudanophilie vasculaire. D'autre part, on a également étudié l'influence sur les éléments nutritifs de deux méthodes différentes de traitement, soit: la cuisson à la vapeur et la friture.

(1) *Analyse des éléments nutritifs*

Des échantillons choisis d'une façon aléatoire sur la production 1956 de 5 industriels différents de l'Etat du Maine ont été analysés pour les éléments nutritifs suivants: protéines, amino-acides, graisses, humidité, cendres, fibres brutes, fer, chlorure, fluor, calcium, phosphates, thiamine, riboflavine, pyridoxine et niacine. D'autre part, l'huile de sardine et le liquide d'emballage ont été caractérisés par l'indice d'iode, les acides gras libres, l'index de réfraction, le cholestérol et la composition des acides gras insaturés.

Les résultats de cette étude montrent que les sardines sont une bonne source pour un certain nombre d'éléments nutritifs comprenant: 23% de protéines, 470 mg.%g. de calcium, 0,133 mg.%g. de thiamine, 4,50 mg.%g. de fluor et 0,133 mg.%g. de pyridoxine. En outre, la distribution des amino-acides est bonne, avec notamment de la lysine en hautes concentrations (9,02% des protéines de la sardine égouttée). De plus, la composition en acides gras de l'huile de sardine tend à être élevée en acides gras insaturés, notamment en acides penténoïques. On a trouvé également des témoignages sur l'existence d'un échange entre le liquide d'emballage et le poisson.

(2) *Disponibilité et utilisation des protéines et des graisses de sardines*

De jeunes rats mâles Sprague-Dawley ont été nourris *ad libitum* avec un régime au gel d'agar-agar, dans lequel soit de sardines, cuites à la vapeur ou frites, soit de la caséine et du saindoux fournissaient toutes les protéines et les graisses. Chacune des trois rations fournissait approximativement 10% de protéines et 6% de graisses, et était donnée durant 5 mois.

On n'a pas trouvé de différences significatives ni dans la croissance, ni dans l'efficacité de la nourriture et des protéines, ni dans la composition de la carcasse, entre les rats nourris à la ration-témoin de caséine-saindoux et ceux qui ont été nourris soit de sardines cuites à la vapeur, soit de sardines frites, comme source de protéines et de graisses. De plus, l'examen histopathologique des animaux nourris de sardines n'a révélé aucune preuve de lésion pathologique quelconque dans tous les systèmes examinés, y compris le système circulatoire.

(3) *Influence sur le cholestérol du sérum et la soudanophilie vasculaire*

De jeunes rats mâles ont été nourris *ad libitum* avec des régimes au gel d'agar-agar contenant 0,5% de cholestérol et 0,25% d'acide cholique. Dans une ration, la caséine et le saindoux étaient les sources de protéines et de graisses, tandis que dans l'autre ration on les avait remplacés par des sardines entières, broyées, égouttées. Les deux rations contenaient chacune approximativement 12% de protéines et 6% de

graisses. Des échantillons de sang étaient prélevés périodiquement pour l'analyse du cholestérol. Dix animaux de chaque groupe furent autopsiés à 55 semaines. Les coeurs et les aortes furent alors teints au Soudan IV, et examinés pour étudier l'ampleur de la soudanophilie.

Une hypercholestérémie sérieuse s'est développée en une semaine chez les animaux nourris aux rations de caséine-saindoux, et elle s'est maintenue tout au long de l'essai. En revanche, les animaux nourris à la ration de sardines n'ont pas présenté d'hypercholestérémie sérieuse pendant toute la période d'essai. Un troisième groupe, nourri au régime de caséine-saindoux pendant sept semaines et ensuite à des régimes de sardines pendant tout le reste de l'essai, a présenté également une sévère hypercholestérémie pendant les sept premières semaines; après le passage aux régimes des sardines, les taux de cholestérol du sérum sont tombés rapidement pour approcher les taux présentés par les animaux nourris de sardines depuis le commencement de l'essai. Des mesures sur la soudanophilie vasculaire ont montré que les animaux nourris aux régimes de caséine-saindoux présentaient une soudanophilie plus marquée que les deux groupes nourris de sardines. Cependant, les animaux qui étaient d'abord forcés avec les régimes caséine-saindoux, avant d'être nourris de sardines, montraient la soudanophilie la plus faible.

(4) *Conclusions*

Les résultats de cette étude indiquent que les sardines, qui sont un produit alimentaire de prix relativement bas, peuvent être considérées comme une bonne source pour un certain nombre d'éléments nutritifs essentiels, surtout pour les protéines et les acides gras insaturés. En outre, les données obtenues démontrent également que chez le rat forcé en cholestérol et en acide cholique, des régimes de sardines peuvent non seulement prévenir une augmentation du cholestérol du sérum, mais encore en réduire le taux chez des rats hypercholestérémiques. De plus, il existe une indication de la capacité des régimes de sardines à inhiber dans une certaine mesure l'accumulation du matériel lipidique dans les aortes et les coeurs de ces animaux.

EL VALOR NUTRITIVO DE LA SARDINA

Se ha realizado una serie de estudios para determinar el valor nutritivo de la sardina (*Clupea harengus*, Atlantic) en función de la distribución de los elementos nutritivos, disponibilidad de proteína y grasa, y su efecto en el colesterol de la sangre y en la sudanofilia vascular. Además, tambien ha sido objeto de estudio el efecto en estos elementos nutritivos dos procedimientos distintos de preparación: cocción al vapor y freidura.

(1) *Análisis de los elementos nutritivos*

Muestras seleccionadas aleatoriamente de la producción de 1956 de cinco industriales diferentes del Estado de Maine fueron analizadas para determinar los elementos nutritivos siguientes: proteína, aminoácidos, grasa, humedad, ceniza, fibra bruta, hierro, cloruro, fluor, calcio, fosfato, tiamina, riboflavina, piridoxina y niacina. Por otra parte, el aceite de sardina y el líquido de envase se caracterizaron por el índice de yodo, ácidos grasos libres, índice de refracción, colesterol y composición de ácidos grasos insaturados.

Los resultados de este estudio indican que la sardina es una buena fuente de varios elementos nutritivos comprendidos proteínas (23%), calcio (470 mg./100 g.), tiamina (0,133 mg./100 g.), fluorina (4,50 mg./100 g.) y piridoxina (0,133 mg./100 g.). Además, la distribución de aminoácidos es buena, en particular en el caso de la lisina que está presente en altas concentraciones (9,02% de la proteína de sardina escurrida). Asimismo, la composición de los aminoácidos del aceite de sardina tiende a ser elevada en ácidos grasos no saturados, particularmente los pentaenóicos. Se han encontrado algunas pruebas de la existencia de un intercambio entre el líquido de envase y el pescado.

(2) *Disponibilidad y aprovechamiento de las proteínas y grasas de sardina*

Jóvenes ratas machos, Sprague-Dawley, se alimentaron *ad libitum* con una ración de gel de agar-agar en la que la sardina, cocida al vapor o frita, o la caseína y la manteca suministraban todas las proteínas y grasas. Cada una de las tres raciones aportaba, aproximadamente, 10% de proteína y 6% de grasa, y se administraron durante 5 meses.

No se encontraron diferencias significativas en el crecimiento, eficacia del alimento y de la proteína, o en la composición de los canales, de ratas alimentadas con la ración testigo de caseína y manteca y animales alimentados con sardina cocida al vapor o frita como fuente de proteína y grasa. Además, el examen histopatológico de los animales alimentados con sardina no reveló prueba alguna de lesión patológica en ningún sistema examinado, comprendido el circulatorio.

(3) *Influencia en el colesterol del suero y la sudanofilia vascular*

Jóvenes ratas machos se alimentaron *ad libitum* con regímenes de gel de agar-agar, que contenía 0,5% de colesterol y 0,25% de ácido cólico. En una ración, la caseína y manteca eran las fuentes de proteína y grasa, en tanto que en la otra las sardinas escurridas, picadas o enteras, substituían a la caseína y la manteca. Ambas raciones contenían aproximadamente un 12% de proteína y un 6% de grasa. Se tomaron periódicamente muestras de la sangre para analizar el contenido de colesterol. Diez animales de cada grupo se sometieron a autopsia a las 55 semanas. Los corazones y aortas se colorearon con Sudán IV, y se examinaron para estudiar la amplitud de la sudanofilia.

Los animales alimentados con las raciones de caseínas y grasa manifestaron en una semana una grave hipercolesteremia que continuó durante todo el ensayo. Por el contrario, los animales alimentados con la ración de sardina no presentaron hipercolesteremia grave durante todo el período del ensayo. Un tercer grupo alimentado con caseína y grasa durante 7 semanas, y con raciones de sardina durante el resto del ensayo, también presentaron una severa hipercolesteremia durante las primeras 7 semanas; después de pasar a la ración de sardina, las concentraciones de colesterol en el suero disminuyeron rápidamente, y se aproximaron a las de los animales alimentados con sardina desde el comienzo del ensayo. Las medidas de la sudanofilia vascular indican que los animales alimentados con caseína y manteca la presentan más marcada que cualquiera de los dos grupos alimentados con sardinas. Sin embargo, los animales que desde el primer momento fueron forzados con la ración de caseína y manteca, antes de ser alimentados con sardina, mostraron la sudanofilia más débil.

(4) *Conclusiones*

Los resultados de este estudio indican que las sardinas, que son un alimento relativamente barato, pueden considerarse como una buena fuente de varios elementos nutritivos esenciales, particularmente proteína y ácidos grasos no saturados. Asimismo, los datos también demuestran que en la rata forzada con colesterol y ácido cólico las raciones de sardina no sólo pueden impedir un aumento en el colesterol del suero, sino que también pueden reducir la concentración de éste en las ratas hipercolesterémicas. Además, existen indicaciones de que la alimentación con sardinas puede inhibir en cierta medida la acumulación de material lipídico en las aortas y corazones de estos animales.

DISCUSSION

On the Review paper submitted by Dr. H. Dam and Dr. E. Lund (Denmark), **Dr. H. S. Olcott** (U.S.A.) observed that, in regard to diets containing 20 per cent cod liver oil, alpha tocopherol acetate has no antioxidant properties *in vitro.*

Prof. O. Notevarp (Norway): *In vivo,* alpha tocopherol acetate *has* antioxidant properties.

Dr. M. M. A. Kader (U.A.R.): There is a relation between vitamin A level and the disappearance of cholesterol from blood serum.

Dr. T. Kaneda (Japan): I believe that my paper will provide additional information on some points.

Dr. G. Borgström (U.S.A.): It is important to be aware of the fact that fish oils also contain 20–40 per cent of saturated acids. In the future, fish oils should be more clearly defined, not only as to their content of tocopherols, but also as to other constituents.

Dr. J. J. Peifer (U.S.A.): I think that one should consider all the polyunsaturated fatty acids, not just the so-called essential fatty acids. Is there a valid correlation between "essential" fatty acid content only of a test diet and blood cholesterol level?

Dr. L. W. Kinsell (U.S.A.): In partial answer to Dr. Peifer's question, there is some evidence that humans, in contrast to rats, may synthesize arachidonic acid, an essential fatty acid, from polyunsaturated acids in fish oils.

On Dr. J. J. Peifer's paper **Dr. M. M. A. Kader** (U.A.R.) asked: Was there any correlation between the degree of unsaturation and the lowering of blood cholesterol levels?

Dr. J. J. Peifer (U.S.A.): There was some correlation, but better correlation was obtained with other lipid analyses. Of greater importance was the shift in fatty acids between different tissues. Apparently, certain tissues have specific requirements for a pattern of fatty acids, and shifting occurs to meet these needs.

Dr. T. Kaneda (Japan): How many milligrams of linoleic acid were fed in your experiments?

Dr. J. J. Peifer (U.S.A.): 10 per cent of fat was fed in our diets; and when linoleic acids or fish oils were fed, one third of the total fat was substituted. Tallow was used at the level of 10 per cent in the controls; and when linoleic acid or fish oils were employed, the fat consisted of two-thirds tallow and one-third linoleic acid or fish oil.

Dr. T. Kaneda (Japan): In our work, cod liver oil, when fed to rats, gave much lower liver cholesterol than when vegetable oils were fed.

Dr. J. J. Peifer (U.S.A.): I should mention that in our experiments bile acids and cholesterol were fed in the preliminary period before the test fats were added to the diet. Under these conditions, only marine oils altered the liver lipid pattern; vegetable oils had no effect.

Dr. G. W. Newell (U.S.A.): Have you followed the deposition of fatty acids in the aorta or plaque? And can these be controlled by diets using fish oils?

Dr. J. J. Peifer (U.S.A.): We have done only limited work in a brief experiment using pooled samples of rat aorta. Marine oils definitely did not promote increases in the aorta lipids, and may even have resulted in some decrease. Our sample size and the limited extent of research does not fully document the decrease.

On Dr. L. W. Kinsell's paper **Dr. J. J. Peifer** (U.S.A.) asked: Would you care to comment on the work of Boetcher who found that arachidonic acid increased for patients at an advanced stage of coronary disease?

Dr. L. W. Kinsell (U.S.A.): It probably depends upon just which tissues were analysed. Lipids in lesions which are metabolically active will be affected by diet, and would contain arachidonic acid. Those at the irreversible stage would not react to diet, and would probably contain less linoleic and arachidonic acid.

Dr. O. R. Braekkan (Norway): What about the question of the extent of ceroids in plaques?

Dr. L. W. Kinsell (U.S.A.): We have not yet done much work on this; but we are deeply interested, as ceroid formation may well be a problem. I wonder if this may not be connected with oxidative changes. Perhaps more attention should be paid to the use of antioxidants in the diet.

Dr. E. Lund (Denmark): If polyunsaturated fatty acids can bring down and keep down blood cholesterol, but cannot prevent dermal symptoms in rats, they are not "essential". If, on the other hand, these polyunsaturateds are converted during metabolism, they should prevent skin symptoms in rats.

On the paper submitted by Dr. O. Notevarp and Dr. B. N. Cyvin, **Dr. E. Lund** (Denmark) asked: Has Dr. Notevarp measured polyunsaturateds in long-term studies? Has he observed any relation between the clinical condition of atherosclerosis or thrombosis, and the increase of polyunsaturated fatty acids in the serum?

Dr. O. Notevarp (Norway): Patients have been followed for two years, with blood cholesterol being measured every month or two. Actually, cholesterol changes very little, but the polyunsaturated fraction showed greater changes.

On the paper submitted by Dr. C. M. Harlow and Dr. A. R. Morton, **Dr. H. Loredo** (Mexico) observed: We had a technical expert in Mexico who did a very good job of publicizing the importance of fish in the diet. In the three districts in which he worked, there was such an increase in demand for fish that the supply was insufficient. This showed that, in addition to educational efforts as advocated by Dr. Harlow, efforts are needed to increase production to meet the new demands, resulting from the education of consumers to eat more fish.

Dr. L. W. Kinsell (U.S.A.): Dr. Harlow indicated that perhaps the time to modify the diet was when the patient had a coronary attack. We have analysed tissues of many patients (after death), and found that an advanced stage of fibrosis and calcification is usually present in patients who have had a coronary attack. That means that this condition has been reached over a period of many years. The condition is probably irreversible at this stage. Tissues from such patients, when extracted, yield insoluble calcium salts of oleic acid, whereas tissues from other patients show higher amounts of linoleic or arachidonic acid. It would seem that the best time to modify the diet is many years before these advanced stages of change have occurred, and while the tissue components are still at a reversible stage.

On the paper submitted by Drs. S. A. Miller, H. A. Dymsza, and S. A. Goldblith, **Dr. F. Soudan** (France) asked whether the reference made to "sardines" should not in fact have been made to "herring".

Dr. S. A. Miller (U.S.A.): In my country the terminology is common: we pack herring and call it sardines.

Dr. G. Borgström (U.S.A.): Vitamin analysis on "sardines" should also cover tocopherols. I suggest wider inclusion of tocopherol data in such studies.

Dr. O. R. Braekkan (Norway): Tocopherol, especially in alcohol form, is unstable, and extreme care is necessary to produce reliable data.

Dr. S. A. Miller (U.S.A.): We are analysing tocopherol contents in synthetic diets.

Dr. G. Borgström (U.S.A.): It is unfortunate that vitamin E (tocopherols) was not included in the vitamin analysis. Without information in this respect, no adequate interpretation seems to be possible as to the distinctive features of these sardines. The lack of data on vitamin E content of fish and fish products is, in effect, deplorable also for another reason. It is quite conceivable that fish may be particularly valuable as a source of vitamin E. This appears a fruitful field for research. It seems indicated that advanced Western countries have not only gradually reduced their *per capita* intake of tocopherol in later decades, but at the same time raised their intake of visible fat.

Section 2c : TRACE ELEMENTS

IMPORTANCE OF MINOR ELEMENTS IN FOOD, ESPECIALLY IN FISH

by

JOACHIM KUHNAU

The nutritional value of fish is not limited by its content in high-quality protein, essential fatty acids, calcium, phosphate, and vitamins. During the last years, evidence has accumulated that fishery products may efficiently contribute also to satisfying the human requirement for essential trace elements. This group of elements includes several metals belonging to the 1st and 2nd by-group of the periodic system (Cu, Mn, Zn, Co, Mo, Cr, V), as well as some metalloids (F, J and Se). They represent catalytically active components of the mammalian and human organism.

While most of them (Cu, Mn, Zn, Co, F, J) have been shown to be essential for normal tissue metabolism and for the maintenance of health in man, the indispensability of other trace elements (V, Mo, Cr, Se) for man has not yet been fully proved, although animal experiments have made it very probable. Knowledge of the functions of trace elements is still restricted; and for some of them (Mn, Zn, Mo, Cr, V, Se) so far no corresponding deficiency diseases in humans are known. However, there is no doubt that these elements have specialized functions in the human body, and therefore must be taken up with the food regularly in appropriate amounts.

Among them, copper takes the first place as the best-known trace element. It is needed for the fixation of iron into hemoglobin, and a deficiency of Cu may cause anaemia even when sufficient dietary Fe is available. In addition, Cu forms an integral part of several oxidizing enzymes. Manganese is necessary for the formation of bones and for the action of pituitary and gonadal hormones. Cobalt, as a component of vitamin B_{12} molecule, takes part in some essential steps of protein metabolism. Zinc activates insulin and is a building stone of various enzymes (carboanhydrase, uricase, lactic dehydrogenase, etc.). Fluorine is connected with the integrity of teeth, and iodine forms part of thyroid hormones. Finally, vanadium depresses cholesterol synthesis and prevents experimental atherosclerosis. Mo, Cr, and Se may be termed "ultra-micro elements", as their requirement figures are extremely low; whether an alimentary deficiency in these elements does occur under practical conditions is still uncertain. Molybdenum, as a flavo-protein component, plays an essential rôle in fatty acid and purine metabolism. Chromium takes part in glucose assimilation, and selenium seems to be a liver-protecting factor.

Considering the manifold and vital functions of these trace elements, nutritionists must look upon fish as a valuable source of them with special interest. Isotope studies have shown that trace elements of sea water are concentrated in muscle and viscera of fish up to 100- to 10,000-fold of the original level, preferentially by fixation to fish proteins. Most of the essential minor elements are present in fishery products in substantial concentrations, which are at least equivalent to those in meat, and on the average much higher than those in vegetables and dairy products. For instance, fish muscle contains as much copper as meat (or even more), 5–10 times more fluorine, and about 100 times more iodine. Zinc can be stored in large amounts in fish muscle and other organs of fish. Sardines are a good source of vanadium. Still higher are the concentrations of trace elements in fish eggs (cod roe), shell-fish, and crustaceans; each of these kinds of seafood may contain 100-1,000 times more Cu, Zn, Mn, Co, J, F, and V than fish itself. While an average serving of salmon, herring or cod may cover more than 20 per cent of the daily need for Cu, Zn, Co, F, or J, the same amount of shellfish, roe, or crustaceans (edible portion) supplies these elements in quantities equal to, or above, the daily requirement. In addition, copper and probably also the other micro-elements of fish muscle are completely absorbed and fully utilized by the human organism. The high content of fish, fishmeal, and other fishery products in minor elements is of particular value in every state of malnutrition, especially when there is a lack of animal protein and an excess of starchy foods (tubers, roots, etc.) which are deficient in these elements. Lack of trace elements may be expected in continental areas far from the seashore, and it may be aggravated by parasitic infestation, as intestinal parasites accumulate enormous amounts of trace metals, thus depriving the host organism of these essential food constituents.

In conclusion, fish, roe, fish meal preparations, shellfish, and crustaceans are a valuable aid in maintaining the balance of trace elements in man, and constitute a preferential dietary supplement wherever a lack of indispensable trace elements is suspected.

SUR L'IMPORTANCE DES OLIGO-ELEMENTS DANS LES ALIMENTS ET EN PARTICULIER DANS LE POISSON

La valeur nutritive du poisson n'est pas limitée par sa teneur en protéines de haute qualité, en acides gras essentiels, en calcium, en phosphate et en vitamines. Au cours des années récentes, on a rassemblé des preuves sur la contribution efficace que les produits de la pêche peuvent apporter pour satisfaire aux exigences de l'homme à l'égard des éléments en traces essentiels. Ce groupe d'éléments comprend plusieurs métaux appartenant aux 1ère et 2ème périodes (larges) de la classification périodique (Cu, Mn, Zn, Co, Cr, Mo, V), ainsi que quelques métalloïdes (F, I et Se). Ils représentent des constituants catalyseurs actifs de l'organisme des mammifères et de l'homme.

Alors qu'on a pu montrer que la majorité d'entre eux (Cu, Mn, Zn, Co, F, I) sont essentiels au métabolisme tissulaire normal et au maintien de la santé chez l'homme, on n'a pas encore complètement démontré la nécessité pour l'homme d'autres oligo-éléments (V, Mo, Cr, Se), bien que celle-ci paraisse très probable d'après des expériences sur des animaux. Notre connaissance des fonctions des oligo-éléments est encore restreinte, et pour quelques-uns d'entre eux (Mn, Zn, Mo, Cr, V, Se) on ne connaît pas de maladies de carence correspondantes chez l'homme. Cependant, il est hors de doute que ces éléments ont des fonctions spécialisées dans le corps humain, et qu'ils doivent être, par conséquent, absorbés régulièrement en quantités appropriées avec les aliments.

Parmi eux, le cuivre, le plus connu des oligo-éléments, prend la première place. Il est nécessaire pour la fixation du fer dans l'hémoglobine, et une déficience en Cu peut provoquer l'anémie, même avec une suffisance de Fe dans les aliments. De plus, Cu représente une partie intégrante de plusieurs enzymes oxydantes. Le manganèse est nécessaire pour la formation des os et pour l'action des hormones de l'hypophyse et des gonades. Le cobalt, comme composant de la molécule de la vitamine B_{12}, prend part à quelques étapes essentielles du métabolisme des protéines. Le zinc active l'insuline, et forme un maillon constitutif de diverses enzymes (carboanhydrase, uricase, déshydrogénase lactique, etc.). Le fluor est en relation avec le bon état de la dentition et l'iode participe à la formation des hormones de la thyroïde. Enfin, le vanadium inhibe la synthèse du cholestérol et prévient l'athérosclérose expérimentale. Mo, Cr et Se peuvent être appelés "ultra-micro éléments", car ils ne sont utiles qu'à très faibles doses; il n'est pas encore sûr qu'une déficience alimentaire de ces éléments puisse pratiquement apparaître. Le molybdène, comme constituant des flavo-protéines, joue un rôle essentiel dans le métabolisme des acides gras et de la purine. Le chrome intervient dans l'assimilation du glucose, et le sélénium semble être un facteur de protection du foie.

A l'égard des fonctions multiples et vitales de ces oligo-éléments, les spécialistes de la nutrition doivent considérer avec une attention particulière le poisson en tant que source de valeur de ceux-ci. Des recherches avec isotopes ont montré que les oligo-éléments de l'eau de mer sont concentrés dans les muscles et les viscères du poisson à des taux qui atteignent 100 à 10.000 fois la concentration d'origine, surtout par une fixation sur les protéines du poisson. La plupart des oligo-éléments essentiels sont présents dans les produits de la pêche en concentrations substantielles, au moins égales à celles de la viande et en moyennes supérieures à celles des légumes et des produits laitiers. Par exemple,

le muscle de poisson contient autant de cuivre que la viande (ou même plus), 5 à 10 fois plus de fluor et 100 fois plus, environ, d'iode. Le zinc peut être stocké en quantités importantes dans le muscle et dans d'autres organes du poisson. Les sardines sont une bonne source en vanadium. Les concentrations en oligo-éléments dans les oeufs de poisson (rogue de morue), dans les coquillages et les crustacés, sont encore plus élevées; chacun de ces types d'aliments marins peut contenir de 100 à 1.000 fois plus de Cu, Zn, Mn, Co, I, F et V que le poisson lui-même. Alors qu'une portion moyenne de saumon, de hareng ou de morue peut couvrir plus de 20% des besoins journaliers en Cu, Zn, Co, F ou I, la même quantité de coquillages, de rogue ou de crustacés (partie comestible) en couvrent la totalité ou plus. En outre, le cuivre ainsi que probablement d'autres micro-éléments du muscle de poisson sont complètement absorbés et entièrement utilisés par l'organisme humain. La haute teneur du poisson, de la farine de poisson et d'autres produits d'origine marine en oligo-éléments est d'un intérêt particulier à tous les stades de la malnutrition, spécialement quand il y a carence en protéines animales et excès en aliments féculents (tubercules, racines, etc.) pauvres en ces éléments. On peut s'attendre à une pénurie en oligo-éléments dans les zones continentales éloignées du rivage maritime, et celle-ci peut être aggravée par la présence de parasites infestants, intestinaux notamment, qui accumulent d'énormes quantités d'oligo-éléments, privant ainsi l'organisme qui les hébergent de ces constituants alimentaires essentiels.

En conclusion, le poisson, la rogue, les préparations farineuses de poisson, les coquillages et les crustacés peuvent valablement contribuer à maintenir le bilan des oligo-éléments chez l'homme, et constituent un supplément préférentiel du régime partout où l'on suspecte une pénurie en oligo-éléments indispensables.

IMPORTANCIA DE LOS MICROELEMENTOS DE LOS ALIMENTOS, PARTICULARMENTE DEL PESCADO

El valor nutritivo del pescado no está limitado por su contenido de proteinas de alta calidad, ácidos grasos esenciales, calcio, fosfato y vitaminas. En los últimos años se han acumulado pruebas de que los productos pesqueros pueden contribuir tambien eficazmente a satisfacer las necesidades humanas de microelementos esenciales. Este grupo de elementos comprende varios metales del primer y segundo periodos largos del sistema periódico (Cu, Mn, Zn, Co, Cr, Mo, V), así como algunos metaloides (F, I, Se). Representan constituyentes catalizadores activos de los organismos de mamíferos, inclusive el hombre. Aunque se ha demostrado que casi todos ellos (Cu, Mn, Zn, Co, F, O) son esenciales para el metabolismo normal de los tejidos y el mantenimiento de la salud del hombre, todavía está por establecerse definitivamente que lo sean otros microelementos (V, Mo, Cr, Se), aunque los experimentos realizados con animales parecen indicar que lo son. Aún es incompleto el conocimiento de las funciones de estos microelementos y en el caso de algunos de ellos (Mn, Zn, Mo, Cr, V, Se) no se han encontrado todavía enfermedades carenciales correspondientes en el hombre. Sin embargo, no hay duda alguna de que desempeñan funciones especializadas en el organismo humano y que tienen que consumirse regularmente con el alimento en cantidades suficientes. De ellos, el cobre, por ser el microelemento mas conocido, ocupa el primer puesto. Se necesita para la conversión del hierro en hemoglobina, y su deficiencia puede causar anemia aun cuando el hierro en los alimentos sea suficiente. El cobre también es parte integrante de varios enzimas oxidantes. El manganeso es necesario para la formación de huesos y para la acción de hormonas hipofisiarias y gonadales. El cobalto, como componente de la molécula de la vitamina B_{12}, participa en varias fases esenciales del metabolismo proteico. El zinc activa la insulina, y es un constituyente de varios enzimas (carboanhidrasa, uricasa, deshidrogenasa láctica, etc.). El fluor está relacionado con una sana dentadura. El yodo forma parte de las hormonas tiroideas. Finalmente, el vanadio deprime la síntesis de colesterol e impide la aterosclerosis experimental. Mo, Cr, y Se pueden denominarse ultramicroelementos, porque la necesidad de ellos es muy pequeña. Todavía no se sabe si en condiciones prácticas ocurre una escases alimentaria de estos elementos. El molibdeno, como componente de las flavoproteinas, desempeña un papel esencial en el metabolismo de ácidos grasos y purinas. El cromio participa en la asimilación de glucosa y el selenio parece ser un factor protector del hígado.

Tomando en consideración las muchas y vitales funciones de estos microelementos, los nutriólogos deben dedicar especial atención al pescado como fuente de ellos. Los estudios de isótopos han demostrado que los microelementos del agua de mar se encuentran en la carne y visceras del pescado, en concentraciones de 100 a 10.000 veces mayores que en el agua, principalmente ligados a las proteinas. Casi todos los microelementos esenciales están presentes en los productos pesqueros en concentraciones sensibles que, por lo menos, equivalen a las de la carne y, en general, sobrepasan con mucho a las de las hortalizas y productos lacteos. Por ejemplo: el tejido muscular del pescado contiene tanto o mas cobre, de 5 a 10 veces mas flúor y unas 100 veces mas yodo que la carne. El zinc se puede acumular en importantes cantidades en la carne y diversos órganos del pescado. Las sardinas son una buena fuente de vanadio. Son todavía mayores las concentraciones de microelementos en las huevas (bacalao), crustaceos y moluscos, que pueden contener de 100 a 1.000 veces mas Cu, Zn, Mn, Co, F, I y V que el propio pescado. Mientras una porción normal de salmón, arenque o bacalao puede satisfacer mas del 20% de las necesidades diarias de Cu, Zn, Co, F o I, la misma cantidad de huevas, crustaceos o moluscos (parte comestible) suministra estos elementos en cantidades iguales o superiores a dichas necesidades. Además, el cobre, y probablemente los otros microelementos de la carne del pescado, se absorven y aprovechan enteramente por el organismo humano. El elevado contenido de microelementos en el pescado, harina de pescado y otros productos de la pesca reviste especial importancia en todos los casos de malnutrición, particularmente en los de falta de proteinas animales y exceso de alimentos amilaceos (tubérculos, raices, etc.) que son deficientes en ellos. La escasez de microelementos puede ocurrir en zonas continentales lejanas del mar y estar agravada por infestación de parásitos, ya que los intestinales acumulan enormes cantidades de ellos y privan al organismo hospedante de estos constituyentes esenciales.

En conclusión, el pescado y sus huevas, los preparados a base de harina de pescado, los crustaceos y los moluscos constituyen una valiosa aportación al mantenimiento del equilibrio de microelementos en el hombre y un complemento preferente de la alimentación siempre que se sospeche falta de estas substancias indispensables.

DISCUSSION

In the discussion on Dr. J. Kühnau's paper, **Dr. G. Borgström** (U.S.A.) observed: The non-edible portions of fish are the most important sources of trace elements, and more use could well be made of them as sources of trace elements. Also, data on the pick-up and concentration of Zn^{65} from seawater into fish tissues would be valuable.

Dr. J. Kühnau (Germany): Yes, it would be interesting to include other organs in our study of trace elements in fish muscle. Zinc is highly concentrated in fish muscle with even higher concentrations localized in some organs. Fillets are poorer in trace elements than whole fish, but fillets still contain greater quantities of trace elements than land-animal meat. Fish flour has 3–10 times the trace element content of meat; fish viscera is of the order of 1,000–10,000 times as high.

Dr. D. P. Cuthbertson (U.K.): What is the rôle of vanadium in atherosclerosis control?

Dr. J. Kühnau (Germany): Vanadium does depress cholesterol in rabbits and rats. Workers in vanadium ores have serum cholesterol levels below those of the surrounding populace.

Dr. D. P. Cuthbertson (U.K.) What is the rôle of chromium in carbohydrate metabolism?

Dr. J. Kühnau (Germany): Chromium seems to be important, along with zinc, in glucose metabolism; but the mechanism is obscure.

Dr. J. J. Peifer (U.S.A.): Vanadium may produce hypocholesteremia, and reduce atherosclerosis; but how about toxic effects?

Dr. J. Kühnau (Germany): Yes, indeed the margin between therapeutic and toxic doses is narrow. Some workers in vanadium ore plants did get toxic effects; but those who did not had lower incidence of atherosclerosis.

Dr. F. Bramstedt (Germany): What is the relationship between the trace mineral elements and the spoilage of fish? Since they are bound to protein, are they not released by degradation of the fish? Are the peptidases activated or inhibited by the release of trace minerals from the protein bond?

Dr. J. Kühnau (Germany): Degradation may change the binding of metals, and liberate them to the active state. Those released metals may activate or inhibit peptidase.

Dr. G. Borgström (U.S.A.): It should be born in mind that trace element analyses only rarely are clearly defined as to the tested sample, whether muscle tissue exclusively, viscera, or remnants of residues. It does appear that caution should be exercised in raising claims as to the consumed fish in this report, particularly as the technological development in advanced countries shows a pronounced trend towards filleting whether fresh, frozen or even canned. With reference to radionuclides, I observed the author did not mention Zn^{65}. As this unquestionably accumulates in the muscle tissue, particular attention should be directed towards this compound. It constitutes an obvious hazard; so that, when we mention the lack of strontium 90 and others as an asset of fish, Zn^{65} may be or become a liability. This point requires expanded research.

Dr. J. Kühnau (Germany): Trace elements are found in higher concentration in the digestive tract or where digestion is going on. This may indicate that they would activate digestive enzymes.

Dr. D. P. Cuthbertson (U.K.): Could we have from Dr. Kühnau further details on the effect of vanadium on depressing cholesterol and reducing experimentally-induced atherosclerosis? Also some further detail on the rôle of chromium in carbohydrate metabolism?

Dr. S. V. Bersamin (Philippines): Dr. Kühnau talked about the efficient activity of planktonic organisms in the fixation and accumulation of trace elements in their constitution. This is especially interesting from the point of view of the nutritional ecology of aquatic organisms like fish. The principal food of fish in any type of aquatic environment is plankton. It would be most interesting, from this point of view, to know if Dr. Kühnau has made studies on the comparative efficiencies of various groups of planktonic organisms in fixing and accumulating trace elements in their bodies. Further, it would be an important contribution to the scientific world to know the definite effects of the various groups of plankton organisms mentioned above, when consumed by fish as food in its chemical composition and nutritive values. Previous studies indicate that chemical composition of aquatic organisms is influenced by the quality of food they eat.

Dr. G. Borgström (U.S.A.): I feel that further discussion has warranted my intervention, and I would strongly urge intensified research in this field. I think Dr. Kühnau would agree with me on this. It is evident that the digestive tract is a far more potent source of the trace elements than the muscle tissue. Another technological factor enters as a complication into this field, namely the efficiency of bleeding. For a good frozen product, the blood has to be removed as well as possible, which presumably reduces the flesh potency as to trace elements. The relationships need to be clarified when we direct ourselves to the general public with claims of nutritive excellence on behalf of fish. Nevertheless, for the sake of the record, I should like to add that it is generally agreed that saltwater fish is a good source of iodine. Furthermore, fluorine is a characteristic feature of seafood, in contrast to most other foods. Fish has a unique merit which might be important to the caries discussion.

PART IV

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EFFECTS OF PROCESSING ON THE NUTRITIVE VALUE OF FISH PRODUCTS IN ANIMAL NUTRITION

by

L. E. OUSTERHOUT and D. G. SNYDER

Variations in the nutritive value of industrial fishery products for animal feeding have been attributed to differences in the raw material, and to changes in nutrient content and availability during the processing and handling of the products. Considerable research still needs to be done to determine the methods most suited for the production of products of highest quality.

For fish meal, which is the principal industrial fishery product, the major variations in nutrient content are caused by differences in the raw materials used and by the extent of nutrient loss or removal during processing, principally in the pressing operation. Fish meal of high quality can be prepared from all species of fish (teleosts), fresh or spoiled, by any of the common commercial methods. The greatest variation in nutrient quality, especially protein availability, is caused by variations in drying, and in subsequent curing and storage. Either vacuum, steam, or direct-heat driers may be utilized for the production of quality meal. The addition of solubles or antioxidant does not appreciably affect the protein quality of the meal.

EFFETS DU TRAITEMENT SUR LA VALEUR NUTRITIVE DES PRODUITS DU POISSON DANS L'ALIMENTATION DES ANIMAUX

Les variations de la valeur nutritive des produits industriels de la pêche pour l'alimentation des animaux ont été attribuées à des différences dans les matières premières et à des modifications dans la teneur et dans la disponibilité des éléments nutritifs pendant le traitement et la manutention des produits.

Il reste encore à conduire un ensemble considérable de recherches pour définir les méthodes qui conviennent le mieux pour fournir des produits de la plus haute qualité.

Pour les farines de poisson, principal produit industriel de la pêche, les variations les plus importantes de la teneur en éléments nutritifs sont dues aux différences dans les matières premières utilisées et à la mesure où se perdent ou même s'éliminent les éléments nutritifs pendant le traitement, et surtout pendant l'opération de presse. Des farines de poisson de haute qualité peuvent être préparées à partir de toutes les espèces de poissons (téléostéens), frais ou abimés, par toutes les méthodes commerciales courantes. La plus grande variation de la qualité nutritive, surtout de la disponibilité en protéines, est entrainée par des variations dans l'opération de séchage et dans les opérations de conservation et d'entreposage ultérieures. Des séchoirs sous vide, par vapeur ou par chauffe directe, peuvent être utilisés pour la production d'une farine de qualité. L'addition de solubilisés ou d'antioxydants n'affecte pas d'une façon appréciable la qualité protéique de la farine.

EFECTOS DE LA ELABORACION EN EL VALOR NUTRITIVO DE LOS PRODUCTOS PESQUEROS EN LA ALIMENTACION DE LOS ANIMALES

Las variaciones en el valor nutritivo de los productos industriales de la pesca en la alimentación de los animales se ha atribuido a diferencias en la materia prima y a modificaciones en el contenido y disponibilidad de los elementos nutritivos durante la elaboración y manipulación de los productos. Se tienen que realizar todavía muchas investigaciones para definir los métodos más convenientes para obtener productos de la mayor calidad.

Para las harinas de pescado, que es el principal producto industrial de la pesca, las variaciones más importantes en el contenido de elementos nutritivos las causan las diferencias en las materias primas empleadas, y en el grado en que los elementos nutritivos se pierden o se eliminan durante la elaboración, principalmente durante la prensadura. Se pueden preparar harinas de pescado de gran calidad a partir de todas las especies de peces (teleósteos), frescos o echados a perder, por cualquiera de los métodos industriales corrientes. Las principales variaciones de la calidad nutritiva, especialmente de la disponibilidad de proteína, se deben a las variaciones en la desecación y, posteriormente, en el curado y almacenamiento. Se pueden emplear secadores de vacío, vapor, o calentamiento directo para la producción de harinas de calidad. La adición de solubles o antioxidantes no influye de manera sensible en la calidad proteica de la harina.

BECAUSE fishery industrial products have an important rôle in the formulation of high-efficiency animal diets, researchers have sought to explain the variation in nutritive quality of these products. Of course, the variations can only be attributed to differences in the raw materials, and to the effects of processing and handling on the nutrient content of the materials. Certain processing variables increase the contents of some nutrients, while decreasing that of others. Inasmuch as high-quality protein is the main nutrient contributed by fishery products, especially fish meal, protein has been studied to the greatest extent; but vitamins, growth factors, minerals, and energy values are also affected during manufacture and handling.

Since fish meal is the principal fishery industrial product, it will be the one primarily discussed in this report, though other products, such as condensed fish solubles, will also be treated.

FISH MEAL

The main topics discussed in this section are (*a*) variables involved in the processing and marketing of fish meal, (*b*) early research, (*c*) effects on nutrient quality of wet rendering, and (*d*) effects on nutrient quality of dry rendering and other methods of manufacture.

PROCESSING AND MARKETING VARIABLES

Most fish meal is produced by wet reduction (1, 2, 3), though smaller quantities are made by dry rendering, or by other methods such as solvent extraction or sun drying. The raw material, consisting either of whole fish caught specifically for reduction or of waste from filleting or from canning, is transported to the reduction plant for storage until it can be processed. The material may be held at ambient temperature, under refrigeration, iced, in refrigerated sea water, precooked, or in any combination of holding temperatures and conditions; and it further may be preserved with salt, nitrite, formalin, or possibly other preservatives. The raw material is then cooked, usually by direct or indirect steam-heated continuous cookers, and pressed to remove a large part of the moisture and oil. The press cake is dried and becomes fish scrap. Many different types and sizes of driers may be used, including batch or continuously fed equipment, heated by steam or direct heat and operating under atmospheric pressure or partial vacuum. The scrap may then be piled in bulk, or sacked, or it may be ground to meal and stored in bulk or sacked. Sometime during the operation, an antioxidant may be added. Depending upon the type of fish from which the meal is produced, it may or may not be cured before shipment. And before it is finally utilized, the meal or scrap may be stored under varied conditions of time, temperature, humidity and aeration prior to being formulated into feed.

Nutrient loss or damage can occur during many of these operations.

EARLY RESEARCH

Most early research on the quality of fish meal was designed to develop the best commercially practicable conditions as related to the main variables of processing. At that time, fish meal was used for a combination of its protein, vitamin and mineral values. Variations in the content or quality of any of these nutrients could cause variations in the results of feeding experiments. It is hard to interpret these early research results, since most materials tested had sketchy processing histories, and it is difficult to evaluate the adequacy of the diets used.

In general, though, before World War II, research on the quality of fish meal as affected by processing variables indicated that the factor contributing most to the variation in fish meal nutritive value—at least in the nutritive value of the protein—was the operation of the drier (4–14). Most work at that time merely compared commercial meals produced by flame, steam, and vacuum driers, and indicated that meal produced in flame driers was usually inferior to those produced in the other types. Evaluation of the meal made from different species of fish indicated that white fish meal was often superior to the meal made from the oily species. As more manufacturers began producing meal primarily for feed rather than for fertilizer, more of the meal from oily species soon became as acceptable as whitefish meal. The quality of fish meal available for feeding purposes improved consistently during this period, as many manufacturers, generally through empirically developed means, improved the processing conditions, which enabled them to make a quite uniform, acceptable product. Only a small part of this development occurred as a result of well-organized and published research.

Changes in the fishing and animal industries caused by World War II created a shortage of animal-protein feedstuffs, and resulted in large-scale use of vegetable protein concentrates for feeding poultry. Until vitamin B_{12} was discovered and manufactured commercially, though, it was almost essential that quantities of animal protein feedstuffs—either fish or meat meal—be included in poultry feeds, since they are good sources of vitamin B_{12}. This change to the use of fish meal primarily as sources of vitamins and other growth factors shifted the direction of research to those processing methods which are most economical and efficient for the preservation of these nutrients. It also resulted in the development of products other than fish meal. These include condensed and dried fish solubles, liquid fish, and fish materials dried on a vegetable carrier as a means for utilizing material, such as stickwater, which previously was discarded, thus extending the available raw material to achieve most efficient use.

After commercial concentrates of vitamin B_{12}, and the other vitamins and unidentified growth factors (UGF), became available, the value of industrial fishery products as vitamin sources fell. In recent years, fish meal has been utilized primarily for its protein value, particularly for its content of lysine and the essential sulphur-containing amino acids, methionine and cystine. Other industrial fishery products, however, and fish meal to some extent, are still used for their UGF value in some poultry rations.

Measurement of the protein quality of fish meal and other protein supplements is a subject upon which no general agreement among nutritionists has been reached. Workers in different parts of the world have usually adopted methods that they consider realistic for their studies. Many laboratories utilize animal trials—most often with young growing chicks or rats—but some use chemical or enzymatic methods, employing animal trials only to check validity. Results obtained with most of the methods are acceptable within limitations.

WET RENDERING

The principle variables involved in wet rendering are (1) raw material, (2) cooking, (3) pressing, (4) drying, (5) curing, and (6) storage. The effect of each of these on nutrient quality will be considered in the following subsections.

(1) Raw material

Fish meal of high protein quality can be manufactured from most of the species of fish (teleosts) which are now commercially available (15–17). Inherent differences in the composition of some species, however, particularly in the amount and type of oil, apparently limit the processing quality control that must be maintained to assure a product of high quality.

Fish meal produced from whole fish has often been thought to be of higher quality than that produced from filleting or canning wastes; but evidence (6, 7, 15–20) indicates that many meals produced from such wastes—including whitefish, redfish, mackerel and herring types—are of as equally high protein quality as those produced from whole fish, though usually of a lower protein content. Meals produced from wastes from some canning operations, however, may be of considerably lower protein content and quality than is most meal made from whole fish. The lower protein content and quality are due possibly to the considerably higher percentage of bone protein and non-protein nitrogen in many of these meals.

The condition and duration of storage of the raw material have a considerable effect on the nutrient content of some fish meals. Industrial fish, handled in whole form, contain active proteolytic enzymes, particularly in the gut; and unless the enzymatic action is prevented or delayed, it will rapidly liquefy visceral and muscle protein (21). If this liquefied protein—which is a mixture of amino acids, peptides, and soluble protein—is lost in the transfer of the fish by pumping or water fluming, the meal produced from the remaining material will have a considerably lower protein and vitamin content than normal. If, however, the soluble materials are conserved, the protein content of the meal produced from the spoiled fish may often be as high as that produced from fresh fish, and the content of some of the vitamins, particularly vitamins B_{12} and K, may even be higher than usual (22, 23). Thus, the chief advantage of rapid handling or refrigeration of the raw material lies in the prevention of loss of nutrients rather than in the maintenance of high quality of protein. A secondary advantage lies in the easier processing of the fresh, firm material than of the soft, mushy, spoiled material, particularly in the pressing operation, thus allowing a more efficient extraction of the oil.

A number of preservatives have been tested, and several are widely used for delaying the spoilage of the raw fish and for aiding the processing of fish softened by spoilage (24, 25). The use of preservatives is particularly advantageous in areas where it permits an extension of the processing time during temporary gluts of fish. Use of sodium nitrite, or formaldehyde, or combinations of both within certain limits, has been shown to preserve the raw fish for practical periods of time, and to cause no detectable injury to the quality of protein. A number of other materials have been tested, but are either lacking in effect or are too costly. Sodium nitrite is probably the most efficient for preservation, but it tends to soften the fish; whereas formaldehyde, at levels high enough to preserve the fish, tends to harden the tissues excessively. Used together, they are quite successful.

Other variables in the handling of the raw material include use of salt as a preservative, particularly in the sardine fishery. In small quantities, this substance has little effect on the meal, except for the increase in content of salt. The higher amount of salt present should be considered in feed formulations using these meals.

Much of the raw material available for reduction in tuna canneries has been pre-cooked, and may be stored before being further processed. Under certain conditions, spoilage occurs resulting in high levels of histamine in the finished meal (20, 26, 27). The histamine formed can adversely affect the growth of chicks fed rations containing high quantities of these meals.

(2) Cooking

Although special processes have been developed which eliminate or combine the cooking step with other operations, most fish being processed for meal are cooked in direct or indirect steam cookers, usually continuously fed. Proper cooking is considered necessary to coagulate the protein and to prepare the raw fish for efficient pressing. It is hard to press undercooked fish and to achieve efficient removal of oil and moisture. The effect of cooking on the nutritive quality of the meal has been the subject of limited studies (28, 29), most of which indicate that properly cooked material has a higher protein quality than uncooked, undercooked, or overcooked material. Whether the improvement due to cooking is an actual improvement in protein quality, or is merely the effect of destruction of deleterious enzymes, possibly thiaminase, has been questioned, but has not been determined. Cooking has been shown to cause small but measurable losses in several of the vitamins.

(3) Pressing

Little or no research has been conducted on the effects of the pressing operation on the nutritive value of fish meal, since in the usual method of manufacture it is an essential step and cannot be easily varied. The protein quality of wet, or of carefully dried, presscake has been shown to be higher than that of the fish meal produced from it, and to be higher than the apparent protein quality of raw fish (28). The improvement in quality has been attributed to the cooking, and the loss in quality to the drying. In the pressing operation, large amounts of some nutrients are removed. These include much of the oil and of some soluble proteins, minerals, and vitamins. Often the soluble materials are saved and concentrated; then they are either marketed as condensed fish solubles or dried solubles, or else the concentrate is added to the presscake for the preparation of a full or whole meal.

(4) Drying

Most early research reports on processing dealt with the effects of different types of driers on the comparative nutritive value of the meals (4–14, 30). Later research has shown that variations in the nutritive value of meals, produced by each of the different types of driers, are much greater than the differences between the mean nutritive value of meals produced by the different types (15–17, 31). To infer that a certain type of drier will produce meal of better or poorer quality than another type requires sufficiently large sampling and testing to enable statistical evaluation. Only recently have several extensive studies been completed that will permit the use of statistical methods. These have shown that all of the commonly used types of driers can produce meal of equally high nutritive value. Meal of lower protein quality is more apt to be produced, however, in hot-air or flame driers than in vacuum or steam driers. A number of studies have shown that heating fish meal protein at temperatures slightly above the boiling point of water does no damage to protein quality until the moisture content of the particles drops to a low level (32). Any further heating then causes a deterioration in the quality. As long as the temperature remains close to the boiling point, though, the loss in quality is slow. A rise in temperature of 20°F above this level will cause a rapid loss in the quality of the protein (32–35). Further rises in temperature will cause burning and charring of particles; indeed, if it is carried far enough, it will completely destroy the protein value. It is interesting to note that badly charred meal may still have near-normal crude protein levels and possess substantial UGF activity (36). There is no particular advantage, with regard to protein quality, of meal dried at the substantially lower temperatures used in some vacuum driers over those dried in properly constructed and operated steam or hot-air driers.

A number of studies (37–42) have shown that some loss of vitamins occur even during the most careful drying of fish materials. Drying under severe conditions destroys high percentages of the vitamins. Loss of vitamins, therefore, is closely related to the loss of protein quality in the meals.

(5) Curing

Proper handling of the scrap and meal after drying is essential for the preservation of nutritive quality. The highly unsaturated oils in fish meals rapidly oxidize and polymerize in the presence of even limited amounts of oxygen (43, 46). These reactions develop considerable heat; and if this heat is allowed to build up, serious damage to protein, and even fire, will occur. Meal differs widely in its reactivity and tendency to heat. Differences have been attributed to species, season, area, type of drier, residual oil and moisture content, addition of solubles, and coarseness of material. It is possible to grind, sack, and ship some low-fat, non-reactive meal, as soon as the scrap emerges from the drier. Other meal can be ground and sacked, but the sacks must be stored in such a manner as to allow the dispersal of heat. Still other material must be handled in bulk form as scrap, and be stirred and aerated to cool for a number of days before it can be ground and handled as meal. Curing is usually continued, either in sack or in bulk, until the reactions slow down enough to allow use of normal methods of handling feedstuffs without danger of fire, caking, or loss of nutrients.

Of the variables listed above as affecting reactivity of the material, producers have greatest control over the residual oil and moisture content. Most meal of high quality is produced with the crude fat content below 10 per cent, and the moisture content as near 8 per cent as possible. The addition of solubles to the presscake before drying tends to lower the reactivity (44–46), possibly by lessening the access of oxygen to the fat. Handling the scrap in a coarse condition decreases the temperature build-up, and makes the necessary cooling and aeration easier.

In recent years a number of producers, particularly those utilizing menhaden, have used antioxidants to reduce the build-up of heat and to extend the space of time in which the scrap piles may be turned. The antioxidant most used is butylated hydroxytoluene (BHT), though a number of others have been tested, and some have proved effective in pilot-plant trials (45–49). The antioxidant is added to the scrap, either when it emerges from the drier or sometime later during the handling of the material. A study of its use shows that, if a sufficient amount is properly dispersed throughout the scrap, the antioxidant will decrease but not eliminate the heating and may thereby aid in preserving the nutritive value of both the fat and the protein. Although use of antioxidants undoubtedly makes it easier for producers in some areas to manufacture fish meal of high quality, the presence of antioxidant in a meal is not a guarantee that the meal is of high quality; high-quality meal can be manufactured even from the most reactive material without antioxidants.

(6) Storage

Studies on changes in the nutritive quality of fish meals during storage have shown that some types of meal remain stable, even when stored for several years, whereas others deteriorate even during a few months of storage (50–52).

Reactive meal has been stored experimentally under an atmosphere of nitrogen at low temperature, and its nutritive quality has remained apparently unchanged for long periods (53). The same meal stored at ambient temperature or in air showed a loss in quality of protein.

Most of the deterioration in nutritive quality during storage has been shown to be a decrease in the digestibility of protein and fat (50–57). Other nutrients contained in the meal are either more stable, or their behavior has not been studied. Again, the types of meal containing the more reactive fats are those that deteriorate most rapidly. Standard analytical procedures indicate normal deterioration by a decrease in amount of ether-extract (53, 54, 57, 58). Values for crude fat as determined by procedures involving hydrolysis show little loss, whereas other milder extraction procedures indicate varying decreases in the amount of extractable fat. Though little definitive work has been reported, it is assumed that the oxidation and polymerization of the fats continue during storage at a rate that varies according to their reactivity and the storage conditions, and that the fats become less digestible. Also, in polymerizing, the fats limit the digestibility of the protein either by physically preventing the digestive enzymes from reaching the peptide bonds or by reacting with the amino acids to form either indigestible or non-assimilable units.

The use of antioxidants has been demonstrated to prevent or delay these deteriorative changes (45–49, 57). Meals stored in the unground form as scrap are also more stable in storage. With some types of meal, storage in sacks rather than in bulk tends to preserve nutritive quality. Some types of products if stored in bulk, either as scrap or as ground meal, should be turned periodically to prevent caking and heating and consequent loss in quality of protein.

DRY RENDERING AND OTHER METHODS

The nutritive quality of fish meal produced by dry rendering should be about the same as that for meals produced by wet rendering (8–11). Dry rendering, however, is considered suitable only for fish containing low levels of fat.

Meal produced by the more primitive methods, such as by sun-drying, is greatly variable in quality (59). Use of lime or excessive quantities of salt to retard putrefication during drying has been reported to limit the general nutritive quality of fish meal manufactured in this manner. Much of this meal contains excessive quantities of sand.

Limited amounts of fish meal are being produced by methods utilizing some type of solvent extraction (18). This meal normally contains very low levels of residual fat, some being almost fat- and odour-free. Although they are generally processed at temperatures considerably below those thought to cause protein damage, meal of these sorts vary considerably in protein quality.

OTHER PRODUCTS

The content of vitamins and unidentified growth factors (UGF) in fish solubles has been shown to vary over a wide range (60). Although a number of factors have been implicated in contributing to the variation, the definite processing conditions that could produce the highest vitamin and UGF contents in the finished material have not been determined. Among the factors believed to influence the nutrient content of the solubles are season, species of fish, freshness of fish and of stickwater, preservatives used, use of proteolytic enzymes, and processing temperature. At present, a considerable portion of the solubles is added to the presscake, and is then dried with it to contribute added nutrient content, especially vitamins and UGF, to the meal. Little work has been published on comparative nutrient values of meal produced with and without added solubles, though recently it has been shown (17) that the quality of protein in the meal is not appreciably affected by the addition of the protein of rather low quality contained in the solubles.

Some fish are processed by liquefaction, either by enzyme digestion (61) or by patented processes, followed by concentration; the product is then marketed as a condensed liquid, is dried into powdered form, or is absorbed on to a vegetable-type carrier and dried. All forms have been shown to possess UGF activity and to contain other vitamins and amino acids. Little work has been reported on comparative nutritive values for these products.

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These pictures are of the same pig. The top one shows the pig at 242 days old after receiving only the controlled ration since birth. It was prostrate owing to instability of its limbs. It appeared to be blind and growth was very sub-normal—only ·5 lb. per day. The bottom picture shows the same animal 48 days later after receiving 2% marine fish oil (cod liver oil) with the controlled ration. It was then normal apart from its awkward stance. The growth rate had increased to 1·21 lb. per day. *Photo by courtesy of British Cod Liver Oils (Hull and Grimsby) Ltd.*

THE BINDING OF LYSINE IN HERRING PRESS-CAKE HEATED UNDER CONTROLLED CONDITIONS

by

K. J. CARPENTER and C. H. LEA

Occasional samples of herring meal show a reduced protein quality and a low content of lysine "available" to react with fluorodinitrobenzene. This binding of lysine E-amino groups is usually attributed to overheating caused by lipid oxidation during storage. With temperature control lipid oxidation caused only slight lysine binding over long periods of storage (Lea, Parr and Carpenter, *Brit. J. Nutr.*, **14**, 91 (1960)).

Freeze-dried press-cake of 9 per cent moisture content lost 50 per cent of its available lysine on heating for 27 hours at 130°. At other moisture contents between 4 and 50 per cent, binding was still over 35 per cent; but in material dried over P_2O_5 it was reduced to 15 per cent. Approximately equivalent damage resulted from 4 hours at 145°, 10 hours at 130° or 27 hours at 115°. Since prior extraction with chloroform-methanol was without effect on the binding produced by heat, lipids play no part in the high-temperature lysine-binding reaction.

Tarr (*Fisheries Res. Bd. Canada, Circular* No. 24 (1960)) drew attention to the presence of ribose compounds in fish meals, and concluded that Maillard (carbonyl-amine) reactions are largely responsible for the damaging effects of overheating. However, the present results are not in keeping with the known characteristics of such reactions; and model experiments on a pure protein, heated with and without small quantities of ribose, suggest that most of the binding is due to cross-linking between groups within the protein molecules.

LA FIXATION DE LA LYSINE DANS LE GATEAU DE PRESSE DE HARENG CHAUFFE SOUS CONDITIONS CONTROLLEES

On observe parfois, sur certains échantillons de farine de hareng, une diminution de la qualité protéique et une basse teneur en lysine "disponible" susceptible de réagir avec le fluorodinitrobenzène. Cette fixation des groupes E-aminés de la lysine est attribuée d'habitude à une surchauffe due à l'oxydation des lipides durant l'entreposage. Avec un contrôle de la température, l'oxydation des lipides n'entraîne qu'une faible fixation de la lysine durant de longues périodes d'entreposage (Lea, Parr et Carpenter, *Brit. J. Nutr.*, **14**, 91, 1960).

Du gâteau de presse cryo-desséché à 9% de teneur en eau perd 50% de sa lysine disponible par une chauffe de 27 heures à 130°. Pour d'autres teneurs en eau allant de 4 à 50%, la fixation dépassait encore 35%; mais pour du matériel séché sur P_2O_5, elle était réduite à 15%. Des dommages à peu près équivalents apparaissaient avec des chauffes de 4 heures à 145°, de 10 heures à 130° ou de 27 heures à 115°. Etant donné qu'une extraction préliminaire à l'acool méthylique chloroformé était sans effets sur la fixation produite par la chaleur, les lipides ne jouent aucun rôle dans la réaction de fixation de la lysine à haute température.

Tarr (*Fisheries Res. Board Canada, Circular* No. 24, 1960) a porté son attention sur la présence de composés du ribose dans les farines de poisson; il est arrivé à la conclusion que les réactions de Maillard (carbonyle-amine) sont largement responsables des dommages résultant de la surchauffe. Cependant, les résultats actuels ne sont pas en accord avec les caractères connus de ces réactions; et les expériences types sur une protéine pure, chauffée avec ou sans de petites quantités de ribose, amènent à croire que al réaction de fixation est due principalement à des liaisons croissées entre groupes à l'intérieur des molécules de protéines.

LA LIGAZON DE LISINA EN LA TORTA DE PRENSA DE ARENQUE CALENTADA EN CONDICIONES REGULADAS

De vez en cuando se encuentran muestras de harina de arenque en las que se observa una proteína de calidad reducida y un bajo contenido de lisina "disponible" para reaccionar con el fluorodinitrobenceno. Esta ligazón de grupos lisina E-amino se atribuye generalmente a calentamiento excesivo causado por oxidación de los lípidos durante el almacenamiento. Regulando la temperatura, la oxidación de los lípidos causó solamente una ligera ligazón de lisina durante largos períodos de almacenamiento (Lea, Parr y Carpenter, *Brit. J. Nutr.*, **14**, 91 (1960)).

La torta de prensa criodesecada con un contenido de humedad de 9% perdió el 50% de su lisina disponible al calentarla durante 27 horas a 130°. A otros contenidos de humedad entre 4 y 50%, la ligazón era todavía superior al 35%. Pero en material seco sobre P_2O_5 se redujo a 15%. Se produjeron daños aproximadamente equivalentes calentando durante 4 horas a 145°; 10 horas a 130° ó 27 horas a 115°. Como la extracción previa con cloroformo metanol no tenía efectos en la ligazón producida por el calor, los lípidos no intervienen en la reacción a elevada temperatura que liga la lisina.

Tarr (*Fisheries Res. Bd. Canada, Circular* No. 24 (1960)) puso de relieve la presencia de compuestos de ribosa en harinas de pescado, y llegó a la conclusión de que las reacciones Maillard (carbonilo-amina) son las principales causantes de los efectos perjudiciales del sobrecalentamiento. Sin embargo, estos resultados no concuerdan con las características conocidas de tales reacciones; y los experimentos modelo con una proteína pura calentada con pequeñas cantidades de ribosa y sin ella, indican que casi toda la ligazón se debe a enlaces cruzados entre grupos dentro de las moléculas de proteína.

Fig 1. Approximate time required to reduce the available lysine in herring meal (6-12% moisture) by 20%

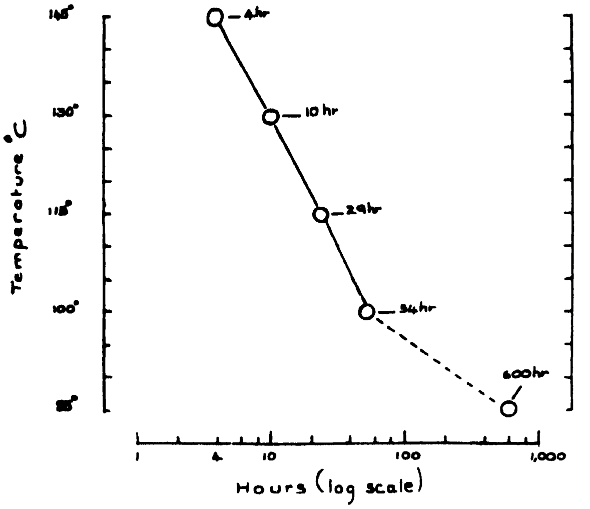
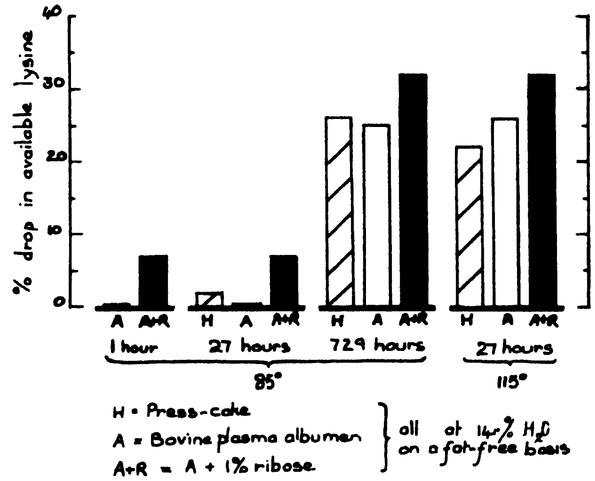


Fig 2. The binding of lysine in press-cake and two models equally heated



While thousands of tons of high quality herring meal are made in the modern factories of highly developed countries, the people in less fortunate areas are obliged to do the best they can with primitive methods. Illustration shows this herring-like fish being sun-dried on the coast of Pakistan ready for export. FAO has suggested that the residue of this fish be made into fish meal to improve the diet of the poultry in the country.

PROBLEMES SOULEVES PAR L'UTILISATION DES FARINES DE POISSON POUR L'ALIMENTATION DES ANIMAUX

par

A. M. LEROY

La crise actuelle dont se plaignent les producteurs de farines de poisson est due d'abord à l'extension relativement récente des fabrications de ces aliments, à la concurrence que leur font d'autres produits d'origine animale ou végétale riches en acides aminés fondamentaux, ainsi qu'aux difficultés éprouvées par les fabricants d'aliments composés à se procurer des farines d'une bonne qualité constante.

Les défectuosités de nombreuses farines de poisson commerciales peuvent provenir d'un degré d'humidité trop élevé, ce qui favorise, au cours de leur conservation, des altérations de caractère chimique ou microbien.

Des teneurs trop élevées en matières minérales et en matières grasses sont incompatibles avec des apports de nutriments azotés suffisamment élevés.

D'autre part, des erreurs dans le traitement de ces marchandises, notamment des températures trop élevées pendant le séchage, peuvent faire disparaître partiellement les acides aminés fondamentaux disponibles, qui constituent les matériaux les plus utiles recherchés par les utilisateurs.

Au fur et à mesure de nos connaissances, la qualité d'une farine de poisson peut s'apprécier par un certain nombre de tests de nature chimique ou biologique. Parmi les tests chimiques, le dosage de l'humidité, des matières minérales solubles et insolubles dans l'acide chlorohydrique, de l'azote total et de l'extrait éthéré posent des problèmes de normalisation, afin d'arriver à ce que les résultats obtenus dans des laboratoires différents puissent être comparables. Il en est de même de la détermination de la teneur en azote ammoniacal.

En ce qui concerne les tests biologiques, la teneur des produites en matières azotées solubilisables par la pepsine chlorhydrique, la teneur en lysine disponible d'après le test de Carpenter ou par l'emploi de tous procédés efficaces ayant le même objectif, d'une part, ainsi que la numération bactérienne pour un poids donné de substance, complétée par la recherche systématique des germes dangereux du genre salmonella, d'autre part, devraient faire l'objet de déterminations effectuées avec l'aide de méthodes également normalisées.

Enfin, la recherche de la présence éventuelle d'amines toxiques, comme la thyramine et l'histamine, protégerait les usagers contre des défauts graves capables d'entraîner, même à très faible dose, des accidents particulièrement dangereux.

PROBLEMS RELATED TO THE UTILIZATION OF FISH MEAL IN ANIMAL NUTRITION

The current crisis affecting fish-meal producers is due in the first place to the relatively recent increase in the number of factories producing this commodity, to the competition they are meeting from other animal or vegetable products with a high amino acid content and, lastly, to the difficulties experienced by manufacturers of compound feeds in obtaining meals of consistently good quality.

Many commercial fish meals may be poor, due to excessive humidity which gives rise to chemical or microbial changes during storage. Too high mineral and fat contents are incompatible with the desired protein levels.

Again, faulty handling, especially overheating in the course of drying, may spoil the available essential amino acids, which are what users of fish meal look for.

Insofar as we know, it is possible to assess the quality of a fish meal by a number of chemical or biological tests. Among the former, tests for moisture content, minerals soluble or insoluble in hydrochloric acid, total nitrogen and ether extraction give rise to problems of standardization. For standardization is what is necessary if the findings obtained in different laboratories are to be comparable. The same applies to the determination of ammonia nitrogen.

As regards biological tests, those for the content of nitrogen soluble in hydrochloric pepsin and for available lysine (Carpenter test or any other efficient method for the same purpose), and bacterial counts supplemented by systematic tests for Salmonella pathogens should themselves be standardized.

Finally, tests for the possible presence of toxic amines (e.g. tyramine and histamine) would guarantee protection to users against serious defects under this head which would otherwise, even with small amounts, have highly dangerous results.

PROBLEMAS RELACIONADOS CON EL EMPLEO DE HARINA DE PESCADO EN LA ALIMENTACION DE LOS ANIMALES

La crisis actual de que se lamentan los productores de harina de pescado se debe, en primer lugar, a la ampliación relativamente reciente de la fabricación de este producto, a la concurrencia de otros productos de origen animal o vegetal con un elevado contenido de aminoácidos esenciales, así como a las dificultades encontradas por los fabricantes de alimentos compuestos para obtener harinas de una buena calidad constante.

Los defectos de muchas harinas de pescado comerciales pueden deberse a un exceso de humedad que durante el almacenamiento favorece las alteraciones de carácter químico o microbiano. Contenidos demasiado elevados de minerales y grasas son incompatibles con concentraciones suficientemente altas de proteínas.

Por otra parte, los errores en el tratamiento, particularmente las temperaturas demasiado elevadas durante la desecación, pueden perjudicar los aminoácidos esenciales disponibles, que son para los usuarios las materias más importantes.

Con nuestros conocimientos actuales, la calidad de una harina de pescado se puede determinar por medio de varios ensayos químicos o biológicos. Entre los primeros, la determinación del contenido de humedad, de los minerales solubles e insolubles en ácido clorhídrico, del nitrógeno total y de los extractos etéreos presentan problemas de normalización que tienen que ser resueltos para que los resultados obtenidos en diferentes laboratorios puedan ser comparables. Ocurre lo mismo en la determinación del contenido de nitrógeno amoniacal.

En cuanto a los ensayos biológicos, los empleados para determinar las materias nitrogenadas solubles por la pepsina clorhídrica, la lisina disponible aplicando el ensayo de Carpenter o por cualquier otro procedimiento eficaz que tenga el mismo objetivo, así como los recuentos bacterianos complementados por la investigación sistemática de gérmenes peligrosos del género Salmonella, deben ser objeto de determinaciones efectuadas mediante métodos igualmente normalizados.

Finalmente, la investigación de la posible existencia de aminas tóxicas (por ejemplo, tiramina e histamina) protegerían a los usarios de defectos graves capaces de producir, aun en dosis muy pequeñas, accidentes muy peligrosos.

L'EXTENSION croissante de la production porcine et de l'aviculture, et surtout les progrès techniques apportés à ces élevages par la vulgarisation de nouvelles connaissances en matière de nutrition et de génétique, a entraîné une demande de plus en plus grande de produits d'origine animale. Les teneurs élevées en matières azotées de ces aliments, ainsi que l'équilibre de leur composition en acides aminés essentiels, leur richesse en vitamines et surtout la présence parmi ces dernières de la vitamine B_{12}, très rare dans les aliments d'origine végétale, les rendent indispensables lorsqu'il s'agit d'obtenir des porcelets et des poulets une croissance en rapport avec les possibilités héréditaires de ces derniers. Parmi ces aliments privilégiés, les farines et les autolysats de poisson méritent une place à part, parce qu'ils proviennent de matériaux excédentaires qui ne sauraient être utilisés directement par les humains, tels que les poissons non commercialisables ou les déchets résultant de certaines préparations (comme, par exemple, celle des filets de poisson).

La présence dans ces produits d'un ou de plusieurs facteurs non encore identifiés, capables d'améliorer la rapidité de croissance des cellules animales, est un argument supplémentaire en faveur de leur emploi.

D'une manière générale, les produits provenant du poisson ne sont pas utilisés directement par les éleveurs. Ces matériaux sont incorporés dans des mélanges équilibrés, à base de substances végétales enrichies de matières minérales et de vitamines. Une industrie en progrès constant, celle des aliments composés destinés à l'alimentation animale, fait appel à ces matériaux pour améliorer l'efficacité de ses multiples spécialités. Pour les jeunes animaux de toutes les espèces, les truies nourrices et les poules pondeuses, il est admis que les rations journalières distribuées doivent contenir, par rapport à la matière sèche, de 16 à 22 % de matières azotées brutes. Or, parmi ces dernières, la théorie et la pratique s'accordent pour reconnaître que les protéines d'origine animale doivent figurer pour un tiers, ce qui explique pourquoi les farines de poisson (et leurs concurrentes, les farines de viande) peuvent être assurées dans l'avenir d'un marché en forte extension.

D'après leur origine, c'est-à-dire d'après la nature des poissons ou déchets de poisson utilisés, d'après l'état de fraîcheur de ces produits au moment de leur traitement, et aussi d'après le moment de l'année où les poissons ont été retirés de la mer, les conditions d'utilisation des farines de poisson peuvent varier d'un échantillon à l'autre. Les modalités du traitement de ces farines pour assurer leur conservation viennent encore accroître les causes de ces variations. Or, si les produits de bonne qualité peuvent être utilisés sans danger d'une manière économique, il n'en est pas de même de ceux d'entre eux dont la valeur alimentaire insuffisante, ou (ce qui est plus grave encore) la présence de produits d'altération suspects risquent de porter atteinte à la bonne réputation des mélanges dans lesquels elles ont été incorporées. C'est en grande partie pour cette raison que l'apparition sur les marchés européens de farines d'une insuffisante qualité a entraîné un déséquilibre entre les offres et les demandes de ces produits, accompagné par une baisse catastrophique des cours. Il est du devoir des fabricants de farines de poisson de bien connaître les causes de modification de la composition chimique des matières premières dont ils se servent, et de rechercher les moyens les plus économiques de les éviter.

Dans une farine de poisson, on remarque d'abord la présence de matières azotées. Les unes sont hydrosolubles, et peuvent donner aisément naissance à un dégagement d'ammoniac. Les autres, formées d'un mélange d'acides aminés parmi lesquels se trouvent les corps les plus essentiels, comme la lysine, les acides aminés soufrés (cystine et méthionine) et le tryptophane, proviennent, soit des tissus musculaires des poissons, soit du squelette de ces derniers. Les protéines des os et des écailles sont accompagnées d'une forte quantité de matières minérales, parmi lesquelles dominent le calcium et le phosphore.

Puisque la matière azotée des farines de poisson représente la partie la plus appréciée par l'acheteur, un tel aliment sera d'autant mieux recherché qu'il contiendra par rapport à l'azote qu'il renferme, moins de matières minérales. Or, les poissons de petite taille, tels que les sardines et les menhadens* renferment proportionnellement plus d'arêtes et plus d'écailles que les gros poissons, comme les saumons, les thons, les squales, etc. Les farines qui proviennent des premiers fournissent, pour cette raison, plus de cendres que celles des autres et sont, à poids égal, un peu moins riches en matériaux énergétiques.

Selon l'origine des poissons traités, la teneur en matière azotée des produits obtenus peut varier entre 50 et 90 %. Ce taux de matière azotée est en relation avec les teneurs correspondantes en matières grasses. Les poissons gras ont tendance, pour cette raison, à fournir des farines moins riches en azote que les poissons maigres.

La teneur en matières grasses des poissons est en relation avec la plus ou moins grande abondance du plancton marin, dont ces animaux se nourrissent. Pour cette raison, toutes les circonstances qui font varier la teneur des fonds marins en plancton exercent une influence sur la teneur en lipides des farines. Parmi ces lipides, les acides gras insaturés, à point de fusion peu élevé, prédominent. Leur proportion relative, par rapport à la masse lipidique totale, est d'environ 75 %. Les plus nombreux d'entre eux sont des corps en C_{20} et C_{22}. Malgré la présence parmi ces derniers de corps qui exercent une action vitaminique favorable, leur excès doit être regardé comme un sérieux inconvénient, parce qu'il possède un effet dépressif sur la fonction laitière des femelles d'animaux domestiques.

D'autre part, les farines exagérément grasses peuvent neutraliser partiellement les vitamines A et E des mélanges alimentaires dans lesquels elles sont incorporées, et se trouver à l'origine d'accidents de carences vitaminiques, qui peuvent avoir sur les jeunes animaux d'assez graves conséquences. Des dystrophies musculaires, par insuffisance de vitamine E, ont été souvent observées chez les poussins à la suite de la consommation de farines de poisson contenant de 20 à 24% de lipides distribuées en trop fortes quantités.

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* Le menhaden est un poisson de petite taille pêché au voisinage de la côte atlantique des U.S.A.

Comme nous le verrons plus loin, la conservation en bon état des farines de poisson pendant leur stockage est d'autant plus difficile à obtenir que ces dernières contiennent une plus forte quantité d'huile.

Enfin, c'est dans la fraction grasse que se trouvent des matières odorantes à odeur et saveur désagréables, qui peuvent traverser la paroi digestive des animaux et donner à leur chair des défauts aisément décelables, s'exacerbant au cours de la cuisson.

Pour toutes ces raisons, en dépit de la valeur énergétique élevée des lipides, il est toujours recommandable de dégraisser par pression à chaud ou par l'action de dissolvants appropriés les produits de poisson destinés à la consommation animale, en sacrifiant ainsi une importante quantité de matériaux calorifiques aisément métabolisables.

Après cet examen sommaire de la composition des farines de poisson, il nous faut étudier les altérations qu'elles risquent de subir, au détriment de leur efficacité nutritive, soit pendant leur préparation, soit au cours de leur stockage.

Altération éventuelle des protéines

(*a*) **Altération avant le traitement.** Lorsque les poissons demeurent trop longtemps hors de l'eau avant d'être traités, la putréfaction de leurs cadavres progresse d'autant plus rapidement que la température extérieure est plus élevée. Il est possible de ralentir cette cause d'altération par l'emploi de glace, par l'usage prudent de faibles quantités de nitrite de soude ou par les deux procédés à la fois; mais, en tout état de cause, la bonne qualité d'une farine de poisson dépend du raccourcissement du délai entre l'instant de la pêche et la mise en fabrication de la matière première. Les farines ayant subi un commencement de putréfaction, facilement décelables par leur mauvaise odeur, renferment des amines toxiques, comme la tyramine et surtout l'histamine, qui peuvent être dosées par une méthode biologique appropriée.

La tyramine, qui provient de la décarboxylation du tryptophane, et l'histamine, engendrée par la désamination de l'histidine, sont des poisons violents, que les traitements subis pour transformer les poissons en farine ne sont pas capables d'éliminer. L'histamine, en raison de son action vasodilatatrice et des chocs anaphylactiques qu'elle entraîne, est la plus à redouter.

(*b*) **Altérations au cours de la dessiccation.** Lorsque les déchets de poisson sont soumis à des températures trop élevées pendant leur dessiccation, la protéine qu'ils contiennent, bien que toujours présente en même quantité, subit des transformations moléculaires qui risquent de réduire fortement son efficacité nutritive.

Le mécanisme d'action de la chaleur peut s'exercer de deux manières. En premier lieu, un traitement trop brutal risque de coaguler certaines protéines, et les rendre partiellement résistantes à leur attaque par les sucs digestifs des animaux. Ainsi peut s'expliquer la diminution de digestibilité de la matière organique, qui peut s'abaisser ainsi de 90% (cas d'une très bonne farine), à moins de 80%.

En second lieu, certains acides aminés peuvent être touchés par la chaleur; et tout en conservant leur structure moléculaire, ils sont rendus inutilisables par les animaux, parce que leurs groupements biologiquement actifs demeurent engagés dans des liaisons peptidiques enzymo-résistantes. La lysine et les acides aminés soufrés sont particulièrement sensibles è ces modifications, ce qui les empêche de jouer leur rôle.

En raison de l'influence de cette action sur l'efficacité biologique des farines, des précautions doivent être prises par les industriels pour l'éviter.

L'expérience a montré que le séchage à la flamme, en four rotatif, pourrait être effectué sans danger à la condition essentielle que la température de la masse en cours de séchage ne dépasse pas, en aucun cas, 160° et que la durée du traitement soit inférieure à 60 minutes. Mais le séchage sous vide, à la vapeur, est de beaucoup préférable, parce qu'il ne porte aucune atteinte aux qualités biologiques de la matière première initiale.

Le traitement par voie humide, qui possède l'avantage de permettre d'enlever l'excès de graisse, est ordinairement suivi d'un passage à la presse, lequel, en éliminant avec les jus de pression les matières azotées solubles, accroît l'efficacité des protides qui demeurent dans la farine. Plur cette raison, une farine pressée est donc plus efficace qu'une autre farine ayant la même teneur en azote, mais qui n'a pas été soumise à ce traitement.

Certaines espèces de poissons, et notamment les squales, contiennent en effet une certaine fraction de leur azote sous forme uréique, dont la valeur alimentaire pour les porcs et les volailles est pratiquement négligeable.

(*c*) **Altération au cours du stockage.** Les mauvaises conditions de stockage peuvent altérer plus ou moins profondément les propriétés physiques, chimiques et biologiques des farines animales. En fonction du temps, en présence d'humidité et à température élevée, une partie des matériaux nutritifs de l'aliment s'insolubilise et ce phénomène s'accompagne d'une modification de la couleur du produit, qui prend une teinte brune.

Les acides aminés sont également modifiés, par amputation d'une partie de leurs groupements NH^2, ce qui ne leur permet plus de servir d'apport azoté à l'animal. Tel est le cas, notamment, de l'arginine, de la cystine et de la leucine. On observe aussi des pertes de vitamines, notamment d'amine nicotinique.

Lorsque les farines trop humides ont été manipulées sans précaution, ce qui leur fait subir des contaminations microbiennes, des altérations avec formation d'amines toxiques peuvent les rendre fort dangereuses. Pour cette raison, une dessiccation poussée de manière à ne laisser dans les farines qu'une quantité d'eau inférieure à 10% est indispensable à l'obtention de farines de bonne qualité pouvant se conserver dans de bonnes conditions.

Altération éventuelle des matières grasses

L'effet du stockage sur les matières grasses est également nuisible. La formation de produits oxydés fait apparaître le goût de rance, ainsi que des substances dont l'odeur désagréable risque de déprimer l'appétit des animaux.

D'autre part, l'huile qui imprègne les farines insuffisamment dégraissées possède une grande surface d'étalement. Son contact avec l'air donne d'abord des peroxydes; puis les acides gras se fragmentent en molécules moins condensées, ce qui augmente à mesure que le temps s'écoule le taux d'acidité des farines, mesurable par les méthodes classiques.

Les peroxydes formés altèrent les vitamines. Le taux de biotine, par exemple, présent dans un mélange composé, dans lequel on vient d'introduire une farine de poisson trop riche en huile, peut diminuer de 20% en 24 heures. Le taux de vitamine A peut également subir une réduction sensible, si le procédé de stabilisation que l'on a utilisé pour la protéger n'est pas parfaitement au point.

Pour éviter ces inconvénients, il faut laisser dans les farines le moins de matière grasse possible.

Il faut refroidir le plus rapidement et dans la plus grande mesure possible la farine après dessiccation, afin de raccourcir au maximum le délai pendant lequel le produit se trouve dans les conditions de température les plus favorables aux phénomènes d'oxydation précités. D'autre part, le stockage devra toujours être effectué dans un local frais et sec.

Afin d'éviter dans une certaine mesure le rancissement au cours de la conservation, l'addition aux mélanges alimentaires de substances antioxydantes est possible et très recommandable, à la condition formelle que ces matières possèdent pour les humains une parfaite inocuité.

Inconvénients d'un excès de matières minérales

Les bonnes farines de poisson ne doivent contenir que des matières minérales provenant des animaux marins, à l'exclusion de toutes autres substances. Certaines farines de crustacés, comme les farines de crabes, donnent à l'incinération des quantités de cendres beaucoup plus grandes que la moyenne, qui proviennent d'un excès de carbonate de calcium. Dans ce cas, le rapport du calcium au phosphore est trop élevé, et les farines de ce genre sont comparables à une farine de viande osseuse que l'on aurait complétée par du calcaire broyé.

Parfois, il est fait usage de sel marin pour conserver les poissons jusqu'au moment de leur dessiccation. Cette addition donne aux farines obtenues des propriétés hygroscopiques, et risque de tromper l'acquéreur en lui faisant payer trop cher un produit qu'il peut obtenir à meilleur compte. Pour cette raison, le dosage des chlorures dans les farines est une opération indispensable; car elle permet de mettre en évidence une anomalie, que les vendeurs ne devraient pas cacher sous peine d'être à juste titre soupçonnés de fraude.

La dessiccation des poissons au soleil, à même le sol, est un procédé primitif qui donne des produits de qualité inférieure. Très souvent, ces farines contiennent du sable, qui provient, soit de l'aire de séchage, soit d'un apport par le vent. En raison du danger que présenterait le mélange frauduleux de tels produits à des farines obtenues par dessiccation artificielle, la recherche des cendres insolubles dans l'acide chlorhydrique bouillant peut mettre en évidence l'existence de matières terreuses anormales dans les farines offertes aux acheteurs.

Préparation, composition et utilisation des autolysats de poisson

Lorsque l'on laisse macérer des déchets de poisson à l'état vert, c'est-à-dire en présence de leur eau de constitution, en les additionnant de sel marin pour obtenir une saumure, des fermentations de nature enzymatique se produisent dans la masse, qui change d'aspect en se liquéfiant.

Depuis longtemps, des produits de ce genre sont couramment utilisés comme condiments dans l'alimentation humaine, notamment en Extrême Orient. La teneur en humidité de ces produits est assez variable, et dépasse souvent 50%. Leur aspect physique ressemble à celui d'un sirop épais comparable à la mélasse, ce qui rend assez difficile leur incorporation dans les mélanges alimentaires solides, lorsque l'on ne dispose pas d'un appareillage approprié.

On peut obtenir aussi des autolysats de poisson à partir de produits solubles, résultant du pressage de la pulpe de poisson en cours de dégraissage.

D'après les analyses qui ont été entreprises jusqu'à ce jour, les teneurs en acides aminés des autolysats de poisson, rapportées à 16 grammes d'azote (c'est-à-dire sensiblement à 100 grammes de matière azotée brute) sont nettement plus faibles que celles des farines proprement dites, ce qui peut s'expliquer par la disparition de ces acides aminés sous des influences enzymatiques.

En particulier, les pertes d'arginine et de lysine peuvent atteindre et même dépasser 50% des teneurs initiales.

Cependant, en dépit de cette réduction, qui peut influencer défavorablement l'efficacité protéique des produits, leur incorporation à faible dose, dans une farine de poisson de bonne qualité, peut améliorer sensiblement l'effet de cette dernière sur la croissance des poulets, sans doute par son action bénéfique sur l'appétit de ces animaux et par la présence de substances vitaminiques dont la composition chimique n'a pas encore été identifiée.

Il existe dans les viscères des poissons, qui sont intégralement contenus dans les autolysats, une thyaminase, dont l'effet est d'agir sur la vitamine B_1 en la transformant de telle manière qu'elle devient incapable de jouer son rôle. C'est à cette thyaminase qu'il faut attribuer l'effet désastreux d'une alimentation exclusivement composée de poissons crus sur les animaux à fourrure. Pour cette raison, l'emploi pour la fabrication des aliments composés de ces autolysats doit être effectué avec précaution et accompagné soit d'une addition de levure sèche, produit riche en vitamines hydrosolubles, soit de vitamine antinévritique synthétique.

Comment reconnaitre une farine de bonne qualité

Pour les fabricants de produits destinés à l'alimentation animale, le choix d'une farine de poisson destinée à être incorporée dans les mélanges destinés aux jeunes animaux est une opération délicate, en raison de la très grande diversité de qualité des produits disponibles sur les marchés.

Un certain nombre de tests, effectués avec soin, peuvent permettre d'apprécier cette qualité avant d'accepter la livraison du produit:

(1°) **Examen de la couleur et de la granulation.** A l'examen visuel, la farine doit être bien homogène et de couleur claire. Elle doit pouvoir passer en totalité au tamis N° 100. La couleur dépend elle-même de l'espèce des poissons traités. La parfaite blancheur n'est pas indispensable, car les farines légèrement colorées, provenant d'autres poissons que ceux à chair blanche, peuvent convenir pour l'alimentation animale. Une couleur trop accentuée, qui pourrait provenir soit d'un excès de chauffage, soit d'altérations au cours du stockage, doit être considérée comme suspecte.

(2°) **Examen de l'odeur et de la saveur.** L'odeur de poisson des bonnes farines est franche et agréable. Il est possible, par des procédés appropriés, de désodoriser complètement ces farines. Dans les farines destinées aux animaux, les produits trop odorants ne doivent être tolérés qu'à faible dose, parce qu'ils risquent de freiner l'appétit et surtout de communiquer à la chair et à la graisse des porcs et des volailles un goût et une odeur franchement désagréables.

(3°) **Dosage de l'humidité.** Le dosage de l'eau contenue dans une farine peut s'effectuer, soit par un séjour de plusieurs heures à l'étuve réglée à 105° centigrades, soit par entraînement à la vapeur de benzine. En aucun cas, le taux d'humidité des farines ne devrait pas dépasser 8 %.

(4°) **Examen des matières azotées.** Il est recommandé aux acheteurs de farines de poisson d'exiger toujours une teneur garantie en azote.

Le dosage de cet élément est effectué par la méthode classique Kjeldahl, dont il serait urgent de normaliser l'emploi sur le plan international.

De nombreux chimistes ont cherché, en effet, à introduire des variantes dans la technique initiale de ce dosage, pour en améliorer à la fois la rapidité d'exécution et la sûreté; mais ces modifications rendent parfois difficilement comparables les résultats obtenus d'un laboratoire à l'autre, dans la mesure où elles risquent d'influencer ces derniers.

En raison de la diminution de digestibilité qu'un traitement trop prolongé ou trop brutal peut apporter à la protéine, il est indispensable de chercher à évaluer par une méthode chimico-biologique le taux d'efficacité nutritive de cette dernière. Le test à utiliser est la digestibilité par la pepsine chlorhydrique, qui permet d'évaluer la proportion de l'azote total solubilisé par la pepsine au pH 2 à 37° centigrades. Dans ces conditions, la quantité d'azote passée en solution au bout de 48 heures doit être d'au moins 90 % de l'azote brut initial.

En raison de l'importance qu'il convient de lui attribuer, les conditions d'application de cette méthode devraient être normalisées, particulièrement en ce qui concerne l'origine et le taux de la solution pepsique à utiliser. A titre d'information, nous donnons en annexe la méthode suivie dans notre propre laboratoire, qui pourrait peut-être servir de base de discussion pour un avant-projet de normalisation.

L'efficacité protéique d'une farine ne dépend pas seulement de sa digestibilité, mais bien essentiellement de la disponibilité pour l'animal des acides aminés fondamentaux qu'elle peut apporter.

Cette disponibilité peut être mise en évidence par la détermination de la valeur biologique de la protéine, faite par la méthode classique sur des rats ou des poussins. Lorsqu'il s'agit de farines destinées aux humains, cette valeur biologique devrait être de 70 %. Pour les farines destinées à la consommation animale, il paraît possible de diminuer cette exigence jusqu'à 65 %.

On peut encore mesurer la valeur de la protéine d'une farine par la détermination de son efficacité protéique pour des animaux de laboratoire. Celle-ci se mesure au moyen du quotient du gain de poids des sujets d'expérience par la quantité de protéine qu'ils ont absorbée.

Malheureusement, l'appréciation de la valeur biologique des farines est une méthode longue et délicate, qui se prête fort mal pour cette raison à des analyses de routine. Il en serait de même pour la détermination par chromatographie des acides aminés libérés au cours de la digestion in-vitro.

Nous devons à Carpenter une méthode chimique qui, malgré quelques difficultés de mise au point, possède l'avantage de fournir rapidement une indication sur la disponibilité dans un aliment de l'acide aminé essentiel qui risque le plus de manquer aux norritures animales, la lysine.

Le test de la lysine disponible (available lysine) permet ainsi de connaître quelle est la fraction de cet acide aminé dont le traitement subi par la farine de poisson a fait disparaître l'activité biologique. Dans une farine de bonne qualité, contenant environ 70 grammes de protéine, (dont 6,3 g. de lysine), la teneur en lysine disponible selon Carpenter doit être de 4,2 g. (soit 6 g. au moins de lysine) pour 16 g. d'azote total de la farine examinée.

Des modifications de la méthode de Carpenter font actuellement l'objet de recherches. Il serait utile de les étudier systématiquement, afin de pouvoir choisir celle d'entre elles qui devrait faire l'objet d'une normalisation sur le plan international.

L'examen des matières azotées d'une farine de poisson ne serait pas complet sans un dosage d'ammoniac. En dehors de l'information apportée par ce dosage sur la teneur initiale en corps uréiques des poissons utilisés, les tentatives de fraude par enrichissement de la teneur azotée au moyen d'une addition d'urée pourraient être ainsi facilement décelées.

En raison du danger que présentent certains aminés toxiques, provenant soit des organes génitaux de certains poissons à l'époque de leur reproduction, soit de fermentations putréfiantes, il est utile de procéder à la recherche de la présence de l'histamine dans les farines. Ceci peut se faire aisément, en observant les effets produits par l'histamine sur une anse intestinale de cobaye isolée de l'animal.

Enfin, on ne devrait jamais oublier de faire, à partir d'un gramme de farine, la numération des germes microbiens qu'elle contient. En ce qui concerne les farines pour les animaux, la tolérance pourrait aller jusqu'à 5.000, mais à la condition formelle que l'on ait vérifié dans cette population l'absence de colibacilles et de salmonella.

Examen de la teneur en matières grasses

Le dosage des matières grasses contenues dans une farine s'effectue conventionnellement par une simple extraction à l'éther sulfurique. D'après ce que nous avons vu précédemment, les meilleures farines sont celles qui ont été le plus parfaitement délipidées. Les exigences des fabricants de farines destinées aux animaux devraient être portées au maximum de 6%.

Bien qu'il soit possible, le dosage des peroxydes n'est pas indispensable, d'abord parce que ces corps ne sont pas par eux-mêmes toxiques, et ensuite parce qu'ils ne sont pas stables, ce qui rend très difficile l'interprétation des résultats fournis par ce test.

Examen des matières minérales

Le dosage des matières minérales, avec examen spécial des quantités de phosphore, de calcium et de chlorures, est facile et indispensable. Selon l'origine des produits, la teneur totale en cendres varie de 12 à 22%. Elle est en moyenne de 17,5%.

A cause de l'eau de mer qui accompagne les poissons jusqu'au moment de leur transformation en farine, une certaine quantité de sel marin se retrouve dans les produits obtenus. Mais cette quantité ne doit pas dépasser 2%. Au-delà de ce pourcentage, il y aurait lieu de soupçonner une addition de sel, qui (comme nous l'avons vu) doit être autant que possible évitée.

La teneur en cendres insolubles dans l'acide chlorhydrique, qui est un bon indice de la contamination par des substances minérales étrangères, doit demeurer au-dessous de 0,5% de la matière sèche totale.

Enfin, en raison de la toxicité du nitrite de soude, qui est quelquefois utilisé pour la conservation du poisson qui vient d'être péché, la présence de ce corps dans les farines doit être systématiquement recherchée. On se souviendra que ce produit est toxique à la faible dose de 0 g. 2 par tête et par jour, pour un animal de la taille d'un mouton ou d'un porc.

Conclusion

Le seul moyen pour les fabricants de farine de poisson de lutter contre les produits concurrents caractérisés par une valeur biologique élevée de leurs matières protéiques, comme les sous-produits des industries de la viande et du lait ou le tourteau de soja, est de soigner avant toute chose la qualité de leurs produits. A cette condition seulement, ils pourront garder et développer dans l'avenir un marché régulier et rémunérateur. Mais il leur faut pour cela faire des efforts, afin de veiller au bon état de conservation de leur matière première initiale, au traitement rationnel de leurs produits en cours de dessiccation, et au deshuilage aussi poussé que possible de leurs farines. Le refroidissement rapide de ces marchandises et leur entreposage dans des sacs conservés à l'abri de la chaleur et de l'humidité sont également indispensables.

Dans ces conditions, les farines destinées soit à l'alimentation humaine, soit à l'alimentation animale, devraient répondre aux normes suivantes:

Projet de normes pour les farines de poisson utilisables à la nourriture des animaux

	Composition moyenne des produits mis sur le marché	*Exigences pour la consommation animale*
Teneur en eau . . .	7,9%	8%
Teneur en mat. minérales	17,5%	max. 20%
dont sel marin . . .		max. 2%
Teneur en cendres insolubles dans HCl		max. 0,5 %
Teneur en protéine brute . .	62%	min. 65,–%
Teneur en protéine digestible à la pepsine	50%	min. 55%
Teneur en lysine par rapport à la protéine	9,1%	min. 9%
Teneur en lysine disponible par rapport à la protéine (selon Carpenter)		min. 6%
Teneur en ammoniac . .		max. 2%
Teneur en lipides totaux . .	6,5%	max. 6%
Teneur en germes microbiens .		max. 5.000

Les indications fournies par le tableau précédent sont données à titre provisoire. Elles devraient, avant d'être adoptées définitivement, faire l'objet d'une très ample et très objective discussion.

Données complémentaires concernant la composition des farines de poisson.

	Acides aminés en % des farines		
	Moyenne	*Minimum*	*Maximum*
Cystine	1,1	0,7	1,6
Glycine	5,0	4,5	5,9
Lysine	6,5	5,3	7,6
Méthionine	2,0	1,7	2,1
Tryptophane	0,7	0,5	0,9

Teneurs de la protéine en acides aminés, rapportée à 16 g. d'azote

	Acide aminés, en g.
Alanine	6,0
Arginine	7,7
Acide aspartique	11,7
Cystine	1,8 ± 0,09
Acide glutamique	13,0
Glycine	6,6
Histidine	2,5
Leucine	8,6
Isoleucine	5,4
Lysine	9,1 ± 0,30
Méthionine	2,4 ± 0,03
Phénylalanine	4,3
Proline	5,9
Serine	4,5
Thréonine	5,1
Tryptophane	0,9
Tyrosine	3,1
Valine	6.1

Variations des teneurs des farines telles qu'elles sont distribuées en quelques acides aminés essentiels.

Répartition de l'azote protéique entre les différents tissus (pour la farine de menhaden)

	% de la protéine totale
Protéine des muscles et des viscères	78
Protéine des tissus de soutien	14
Protéine hydrosoluble	8

Rapport $\frac{P}{Ca}$ dans les farines:

moyenne	*minimum*	*maximum*
0,56	0,45	0,75

Teneurs en quelques micro-éléments, en mmg. pour 100 g. de farine

	Poissons communs	*Requins*
Fer	de 150 à 200	
Cuivre	de 2 à 18	100
Manganèse	de 8 à 22	80

Teneurs en vitamines, par rapport aux farines telles qu'elles sont distribuées, par Kg de produit

B_{12}	76 à 1050 g.[1]
Biotine	0,15 mmg.
Choline	2200 à 8800 mmg.
Acide folique	2,4 mmg.
Niacine	24 à 350 mmg.
Acide pantothénique	9,- mmg.
Pyridoxine	6,5 mmg.
Riboflavine	5,7 à 9,5 mmg.
Thiamine	0,45 à 0,90 mmg.

[1] La donnée maximum a été observée sur des farines de sardines.

Méthode pour l'épreuve de la digestibilité enzymatique in-vitro

I. Doser à part l'azote Kjeldahl et l'humidité sur le produit brut.
II. Introduire 2 g. de produit dans un flacon Erlenmeyer de 500 c.c. Ajouter:
  250 c.c. d'eau distillée
  3 c.c. de HCl 2,5 N
  25 c.c. de solution pepsique aqueuse à 5 p.mille (agiter la solution avant usage).

Boucher le flacon avec un bouchon de caoutchouc; le porter pour 24 heures à l'étuve ou au bain-marie à 37°. Agiter de temps à autre.

Ce laps de temps écoulé, ajouter une quantité de HCl 2,5 N qui permette d'établir le pH du milieu aux environs de 2,0 (1,5 à 2 c.c. de HCl 2,5 N suffisent habituellement). Vérifier l'acidité au papier réactif (papier pH sensible): si le pH est supérieur à 2, rajouter du HCl de manière à ramener ce pH au voisinage de 2,0–1,7. Remettre à l'étuve ou au bain-marie pour une nouvelle période de 24 heures en agitant de temps à autre.

A l'issue de ce délai, filtrer le contenu du flacon sur entonnoir Büchner, de manière à recueillir soigneusement la fraction solide (la filtration est facilitée par de l' "hyflo-supercel" et un vide partiel). Sur le filtrat, vérifier au papier réactif le pH final, qui doit être compris entre 1,7 et 2,2. Dans le cas contraire, recommencer l'épreuve de digestion en ajustant différemment l'addition de HCl. Laver le flacon Erlenmeyer et le filtre 3 fois à l'eau distillée chaude et recueillir tout l'insoluble pepsique sur le filtre.

Assécher le filtre et son contenu à l'air libre ou à l'étuve; le transvaser dans un matras Kjeldahl; minéraliser selon la technique de Kjeldahl, après avoir laissé digérer quelque temps le filtre par l'acide sulfurique concentré froid, ajouté à la dose habituelle; doser l'azote.

Compléter éventuellement l'épreuve pepsique par une détermination de N ammoniacal et de N uréique (si l'on suppose la présence d'urée dans le produit) par les méthodes conventionnelles admises.

Réactifs à préparer:

HCl 2,5 N:
  250 c.c. de HCl pur RP (d = 1,18) dilués à 1.000 c.c. avec de l'eau distillée;
  solution aqueuse à 5 p.mille de pepsine UCLAF titre 200.

(*Remarque:* la pepsine en poudre se conserve plusieurs mois à l'abri de l'air et de la lumière, en flacons soigneusement bouchés.)

eau distillée.

Calculs:

Index de digestion pepsique (d_p)

$$d_p = \frac{\left(N\,\begin{matrix}\text{initial}\\ \text{introduit}\end{matrix} - N\,\begin{matrix}\text{résiduel de}\\ \text{l'insoluble pepsique}\end{matrix}\right)}{N\ \text{initial introduit}} \times 100$$

Teneur de la farine animale en azote digestible à la pepsine HCl:

N digestible % de produit sec $= N \times \frac{d_p}{m}$

ou:
  N — teneur en azote brut % de produit; on pourrait éventuellement défalquer de cette valeur les teneurs en N ammoniacal et en N uréique;
  d_p — index de digestion pepsique;
  m — teneur en matière sèche % de produit.

Note: Dans le cas d'une farine grasse, un dégraissage préalable est nécessaire; pour cela, introduire les 2 g. de produit dans un extracteur de Soxhlet et extraire durant deux heures à l'éther bouillant; transférer soigneusement le produit dégraissé, débarrassé des restes de solvant par une courte exposition à l'air libre, dans le flacon Erlenmeyer servant à l'épreuve de digestion in-vitro.

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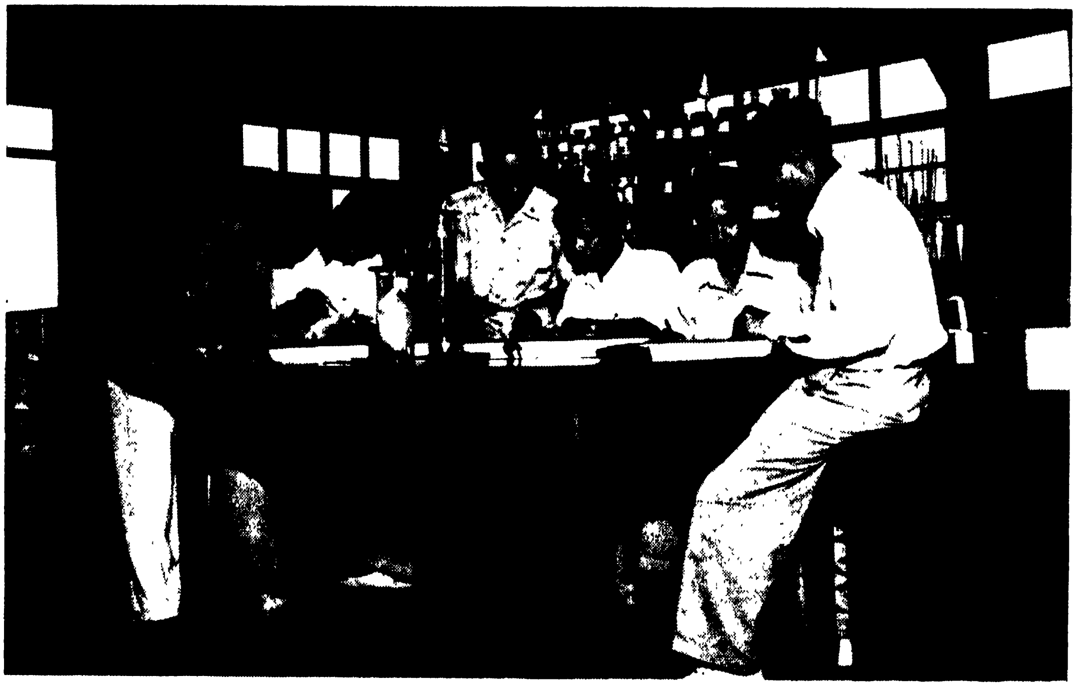


The quality of fish meal made under many different conditions and from varying species must of course vary and it is necessary that chemical tests be carried out to standardize quality. This and other work on fisheries represents an expanding field of activity in which many new hands are required. To provide those workers FAO supplies many instructors to different countries on request. Illustration shows pupils in Thailand watching a simple demonstration of laboratory technique by a visiting FAO expert.

NUTRITIVE CONSTITUENTS OF FISH MEAL AND FISH SOLUBLES

by

SHIGEO MURAYAMA and MASAAKI YANASE

Demand and supply of fish meal and fish solubles in Japan, both as food for farm animals and as fertilizer, have been increasing year after year. However, nutritive constituents of these products vary widely. This is because various kinds of fish (including pollack, cod, sardine, saury, tuna, cuttle fish, etc.) are used, in either round form or as waste, for processing into fish meal or fish solubles. Processing methods are also various, depending on type of material and market requirements.

Most fish meal studies conducted so far are limited to assessing contents of protein, fat, and ash. Still less is known about nutritive constituents of fish solubles. The authors have examined various brands of commercial fish meal and fish solubles for vitamin content and mineral composition, as well as general composition.

Experiments and results: Fish meal

One group of materials used for the present study comprises 7 samples of fish meal produced in Japan in 1958 and 1959. Another group includes 6 samples from various other countries. The results of analysis are shown in Tables I and II. In comparison with the samples produced from such materials as fish waste, miscellaneous small fish and crustaceans, sample No. 1, which was processed from whole fish bodies of fish, contained crude protein (66·5 per cent) and vitamin B_6 (7·2 per cent) at a higher level, but moisture (7·1 per cent) and crude ash (16·9 per cent) at a lower level (Table I). No remarkable differences in composition of nutritive elements were observed between Japanese fish meal and the products of other countries.

Fish solubles

Ten samples of fish solubles produced in Japan in 1960 were analysed. The results of analysis given in Table III indicate that moisture content of each sample was less than 50 per cent; crude protein content ranged from 35 to 49 per cent, and crude ash content did not exceed 11 per cent. Fish solubles had higher vitamin A content levels than fish meal. Vitamin content was considerably high, especially pantothenic acid (15·0–49·5 γ/g.) and vitamin B_{12} (16·112 γ/100 g.). The amounts of calcium, phosphorus, and Ca/P in fish solubles were remarkably lower than those in fish meal.

CONSTITUANTS NUTRITIFS DE LA FARINE ET DES SOLUBILISES DE POISSON

La demande et l'offre de la farine de poisson ou des solubilisés de poisson comme aliments pour les animaux domestiques et comme fertilisants se sont accrues chaque année au Japon. Cependant, les constituants nutritifs de ces produits varient très largement. Ceci est dû au fait que de nombreuses variétés de poisson (comprenant le colin jaune, la morue, la sardine, le saurel, le thon, le calmar, etc.) sont utilisés, soit sous leur forme entière, soit comme déchets pour être traités en farine de poisson ou en solubilisés de poisson. Les méthodes de traitement sont diverses aussi selon le type de matière première et les exigences du marché.

La plupart des études faites jusqu'ici sur la farine de poisson sont limitées à la détermination des teneurs en protéine, graisse et cendres. On en sait encore moins sur les constituants nutritifs des solubilisés de poisson. Les auteurs ont étudié divers mélanges de farines industrielles de poisson et de solubilisés de poisson pour leur teneur en vitamines et leur composition minérale, comme pour leur composition générale.

Expériences et résultats: Farine de poisson

Un groupe de produits utilisés pour la présente étude comprend sept échantillons de farine de poisson produite au Japon en 1958 et 1959. Un autre groupe comprend 6 échantillons venant de divers autres pays. Les résultats des analyses sont présentés dans les Tables I et II. En comparaison avec les échantillons provenant de matières premières telles que les déchets de poisson, les petits poissons de refus et les crustacés, l'échantillon n° 1 qui a été obtenu depuis des corps entiers de poisson présente une teneur plus haute en protéine brute (66,5%) et en vitamine B_6 (7,2%), mais moindre en eau (7,1%) et en cendres brutes (16,9%) (Table I). On n'a pas observé de différences notables dans la composition des éléments nutritifs entre la farine alimentaire japonaise de poisson et les produits des autres pays.

Solubilisés de poisson

On a analysé 10 échantillons de solubilisés de poisson produits au Japon en 1960. Les résultats des analyses sont donnés en Table III; ils indiquent que la teneur en eau de chaque échantillon est inférieure à 50%, que la teneur en protéine brute varie de 35 à 49%, et que la teneur en cendres n'excède pas 11%. Les solubilisés de poissons présentent des teneurs en vitamine A plus élevées que la farine de poisson. La teneur en vitamines est considérablement élevée, spécialement en acide pantothénique (15,0 à 49,5 γ/g.) et en vitamine B_{12} (16 à 112 γ/100 g.). Les solubilisés de poisson présentent des quantités de calcium et de phosphore et un rapport Ca/P notablement plus faibles que la farine de poisson.

CONSTITUYENTES NUTRITIVOS DE LA HARINA Y SOLUBLES DE PESCADO

Le demanda y la oferta de harina y solubles de pescado en el Japón, como alimento para los animales domésticos y como fertilizante, han aumentado de año en año. Sin embargo, los constituyentes nutritivos de esos productos varían mucho debido a que muchas variedades de pescado (comprendido abadejo, bacalao, sardina, paparda, atún, calamar, etc.) se usan enteros o como desechos para reducirlos a harina o solubles de pescado. Los métodos de fabricación son igualmente diversos y dependen del tipo de materia prima y de las exigencias del mercado.

Casi todos los estudios sobre harina de pescado realizados hasta ahora se han limitado a determinar el tenor de proteína, grasa y ceniza. Se sabe todavía menos de los constituyentes nutritivos de los solubles de pescado. Los autores han estudiado varias marcas de harina y solubles de pescado industriales, para determinar el contenido de vitaminas y la composición mineral, así como la composición general.

Experimentos y resultados: Harina de pescado

Un grupo de productos empleados en el presente estudio comprende 7 muestras de harina de pescado preparada en el Japón en 1958 y 1959. Otro grupo abarca 6 muestras de varios otros países. Los resultados de los análisis se dan en las Tablas I y II. En comparación con las muestras preparadas a partir de materias primas como desechos de pescado, morralla formada por pescado pequeño y crustáceos, la muestra número 1 preparada con el cuerpo entero del pescado contenía una importante cantidad de proteína bruta (66,5%) y vitamina B_6 (7,2%) y menos humedad (7,1%) y ceniza bruta (16,9%) (Tabla I). No se observaron diferencias notables en la composición de los elementos nutritivos de harinas de pescado japonesas y los productos de otros países.

Solubles de pescado

Se analizaron 10 muestras de solubles de pescado producidos en el Japón en 1960. Los resultados de los análisis, dados en la Tabla III, indican que el contenido de humedad de cada muestra es inferior al 50%; el de proteína bruta oscila de 35 a 49%; y el de ceniza bruta, no pasa de 11%. Los solubles de pescado contenían mayores concentraciones de vitamina A que la harina de pescado. El contenido de vitamina era elevadísimo, particularmente el de ácido pantoténico (15,0–49,5 γ/g.) y vitamina B_{12} (16–112 γ/100 g.). Las cantidades de calcio y fósforo y la relación Ca-P en los solubles de pescado es notablemente más baja que en la harina de pescado.

TABLE I

Nutritive elements of fish meal produced in Japan

	General composition				*Inorganic substance*			*Vitamin*						
Sample No.	*Moisture* %	*Crude fat* %	*Crude protein* %	*Crude ash* %	*Ca mg.%*	*P mg.%*	*Fe mg.%*	*A IU/g.*	*B_1 γ/g.*	*B_2 γ/g.*	*B_6 γ/g.*	*Pantothenic acid γ/g.*	*Folic acid γ/100g.*	*B_{12} γ/100g.*
1	7·1	4·7	66·5	16·9	5280	3560	23·0	8·8	0·5	2·5	7·2	6·0	12	4·8
2A	11·8	6·9	54·4	23·8	7660	3725	76·8	2·4	7·6	7·5	1·8	6·4	25	7·5
2B	12·0	8·1	53·2	21·7	6770	3910	45·5	3·0	2·0	4·1	2·3	5·6	88	5·4
3A	11·9	13·1	56·1	14·1	4540	2135	44·5	3·4	0·8	3·3	1·4	4·3	42	11·0
3B	12·1	5·0	56·0	20·0	5950	3575	88·2	2·6	1·3	4·3	1·8	3·9	40	5·0
4	16·5	1·6	30·8	29·2	7400	1630	45·0	2·8	0·5	1·6	1·8	10·0	520	2·2
5	13·5	2·9	32·4	29·6	8750	670	264·0	1·0	1·1	6·4	1·6	7·6	34	0·8

Sample No. 1 processed from flat fish, cod and Alaska pollack
„ „ 2 processed from Alaska pollack waste
„ „ 3 processed from miscellaneous small fish
„ „ 4 processed from crab
„ „ 5 processed from isopod, a kind of crustacean

TABLE II

Nutritive elements of fish meal produced in various countries

		General composition				*Inorganic substance*			*Vitamin*						
Sample No.	*Material and Source*	*Moisture* %	*Crude fat* %	*Crude protein* %	*Crude ash* %	*Ca mg.%*	*P mg.%*	*Fe mg.%*	*A IU/g*	*B_1 γ/g.*	*B_2 γ/g.*	*B_6 γ/g.*	*Pantothenic acid γ/g.*	*Folic acid γ/100g.*	*B_{12} γ/100g.*
1	Cod, Iceland . . .	9·0	2·8	67·1	19·6	5970	3980	68·5	1·8	10·3	4·8	18	14	16	4·0
2	Redfish, Iceland . .	8·5	10·9	59·5	18·5	5980	3860	29·7	7·0	0·6	2·9	10	10	30	6·0
3	Herring, Norway . .	9·7	7·0	66·8	12·1	1950	2570	31·7	8·9	1·4	5·2	8·0	21	30	5·6
4	Unidentified fish, Portugal	8·3	9·4	52·1	24·9	5220	3430	59·0	3·3	0·7	1·3	2·8	9·4	20	5·6
5	Anchovy, Peru . .	8·5	5·8	64·6	13·9	4470	3060	30·3	4·5	0·3	2·5	14	9·3	16	18
6	Pilchard, Angola . .	7·6	5·0	64·2	19·0	5720	3910	49·3	5·1	0·3	5·1	8·0	7·0	20	14

TABLE III

Nutritive elements of fish solubles produced in Japan

		General composition				*Distribution of Nitrogen*	
Sample No.	*Material*	*Moisture* %	*Crude fat* %	*Crude protein* %	*Crude ash* %	*Ratio of water soluble N to total N* %	*Ratio of volatile basic N to total N* %
1A	Tuna viscera	41·8	7·7	44·9	3·4	91·4	2·2
1B	Tuna viscera	43·6	10·0	40·2	3·7	79·2	2·6
2A	Alaska pollack and Atka mackerel flesh mixed with viscera	40·4	11·2	38·2	4·6	86·4	4·3
2B	Alaska pollack and Atka mackerel flesh mixed with viscera	46·5	10·0	35·2	4·0	87·7	4·1
3	Squid, saury, Alaska pollack and salmon flesh mixed with viscera	40·7	6·6	41·6	10·1	96·8	3·2
4A	Unidentifiable	40·4	5·2	45·7	4·6	93·4	2·7
4B	Unidentifiable	33·8	8·9	48·2	6·4	82·5	2·7
4C	Unidentifiable	37·3	10·0	46·5	4·1	89·2	3·7
4D	Unidentifiable	42·3	4·6	46·8	4·1	85·9	2·6
5	Cooked liquor of skipjack flesh	42·6	4·1	38·8	10·8		

TABLE III (*continued*)

Nutritive elements of fish solubles produced in Japan

	Vitamin									Inorganic substance									
Sample No.	A IU/g.	D IU/g.	B_1 γ/g.	B_2 γ/g.	B_6 γ/g.	Niacin mg./100g.	Pantothenic acid γ/g.	Biotin γ/100g.	B_{12} γ/100g.	Ca mg.%	P mg.%	Fe mg.%	K mg.%	Na mg.%	Mg mg.%	Sand %	Silicic acid %	SO_4 mg.%
1A	271		0·07	5·6	6·6	14·7	25·5	80	20	27·3	508	44·8	250	96	68·0	0·71	0·91	3·91
1B	718	115	0·05	4·6	7·8	14·3	20·5	53	18	79·3	552	28·7	215	112				
2A	436		0·04	6·7	1·6	11·3	24·5	216	20	65·4	768	24·7	281	136				
2B	479			5·8	3·4	23·1	24·5	140	20	59.8	715	15·8	531	172	34·6	1·09	0·42	84·8
3	33			3·4	13·0	27·1	15·0	56	16	35·2	883	18·7	952	280				
4A	344			3·9	5·8	22·3	38·5	116	23	61·8	707	30·2	300	128	31·0	0·31	0·26	4·91
4B	81	36		6·2	2·0	22·5	24·0	80	112	39·0	753	23·3	340	232				
4C	413		0·12	2·5	11·0	26·8	22·0	80	20	43·5	553	36·5	262	125				
4D	352			3·4	8·6	19·5	17·5	70	23	42·2	560	33·3	331	108				
5	3		5·40	11·3	15·0	50·0	49·5	43	25	29·8	871	20·9						

DISCUSSION

On the paper submitted by Dr. L. E. Ousterhout and Dr. D. G. Snyder, Dr. H. L. A. Tarr (Canada) observed: As a result of a great deal of comparative work on fish meals, it was found that the nutritive values of British Columbia herring meals are higher than those of the other meals.

Dr. H. R. Bird (U.S.A.): Might not this superiority be due to less heating?

Dr. H. L. A. Tarr (Canada): Oils in herring meal are less unsaturated, and consequently less prone to heating.

Dr. L. E. Ousterhout (U.S.A.): Herring meals are no better or worse than menhaden or whitefish meals. Meals must be treated carefully to preserve the digestibility of the oils, and consequently that of the proteins.

Dr. G. M. Dreosti (South Africa): Studies on horse-mackerel and pilchard meals showed the former to be slightly more stable than the latter. Heat damage is related to moisture content of the meals; if moisture is low, damage is less. The oil from pilchard meal is highly unsaturated. Meal stability is dependent upon the species and moisture content of the meal.

Dr. L. E. Ousterhout (U.S.A.): Some meals are more stable than others, and natural antioxidants in the meal are important factors tending toward greater stability.

Dr. H. S. Olcott (U.S.A.): There are two reactions. The first is the oxidation of lipids, to give carbonyls and aldehydes which react with proteins; this oxidation is inhibited by moisture content up to about 8–12 per cent. The second reaction is browning, due to the Maillard reaction of aldehyde; browning is accelerated at a moisture content of about 15–20 per cent.

Dr. L. W. Kinsell (U.S.A.): What antioxidants are considered best?

Dr. L. E. Ousterhout (U.S.A.): Stantiquin is equal to, or more effective than, BHT as an antioxidant for fish meal. Both have been accepted by the U.S. Food and Drug Administration.

Dr. M. A. Raafat (U.A.R.): Good meals have a low fat content, while low quality meals have a high fat content.

Dr. L. E. Ousterhout (U.S.A.): Certain species have stable fats, and some fish meals of best quality might contain 15–18 per cent fat (herring). With a reactive fat such as that of menhaden meal, quality is related to fat content.

Dr. K. J. Carpenter (U.K.): According to Ousterhout's paper, one should try to minimize the oil content of fish meals. Could one extract the oil, fractionate or hydrogenate it, and add it back to the meal?

Dr. G. M. Dreosti (South Africa): Once you remove the oil, there would be no point in adding it back. Fish meal and fish oil should be treated as separate products.

Dr. D. G. Snyder (U.S.A.): Since the current trend is to incorporate more fish meal into rations, a low oil content would be desirable because of the decreased possibility of a fishy flavour in the flesh of the consuming animals (broilers).

Prof. A. M. Leroy (France): Should the meal be allowed to cool naturally, or should some mechanical means be employed?

Dr. L. E. Ousterhout (U.S.A.): In the United States several methods of cooling are used, such as air blowing, or elevating the meal and sifting it through the air from a height of 60 feet or more, and then perhaps repeating this lifting and sifting a second time. Long metallic conveyors also have a cooling effect. Meals should not be cooled in piles, unless they are very small.

Dr. K. Breirem (Norway): In 1956 experiments were begun in Norway to study the effect of adding the antioxidant BHT during the manufacture of herring meal. The antioxidant-treated fish meal was sun-dried, in comparison with non-treated herring meal. (The results will be published in one or two years). The treated and non-treated herring meals proved to be of equal nutritive value. We are of the opinion, therefore, that a well-stored, mildly oxidized Norwegian herring meal can be used without any risk. It seems that impairment in the nutritive value may occur only in the initial active stage of oxidation; this corresponds with my observations on the impairing effects of combines on freshly harvested grain in Scandinavian countries. An interesting observation made during our experiments on antioxidant-treated herring meals should be mentioned: it was found that this herring meal produced significantly more fishy odours in lard and pork than non-treated meal. The use of antioxidants in the manufacture of fish meals would appear to be inadvisable when the meal is to be used by swine.

Problem of inspection

On the paper submitted by Prof. A. M. Leroy, Dr. D. G. Snyder (U.S.A.) observed that the presence of toxic bacteria in fish meal was not a problem in the United States.

Dr. G. Borgström (U.S.A.): A whole group of salmonella was introduced into Europe. It is unfortunate that this has occurred in fishery products, since it has led people to believe that there is something inherently dangerous about fish. Actually this contamination most probably occurs during processing and distribution, since it does not occur in the living fish. The salmonella infection has spread into poultry and humans in Europe.

Dr. A. M. Leroy (France): The Pasteur Institute found certain fish meals to have high concentrations of salmonella, and so to be dangerous.

Dr. E. M. Del Solar (Peru): The existence of salmonella in fish meal is undoubtedly due to contamination of the product after it has left the production plant.

Dr. G. Varela (Spain): In general, toxicity in fishery products is related to the presence of toxic amines.

Dr. G. Borgström (U.S.A.): It is found generally that contamination can occur in the handling, processing, and distribution of the meals. In spite of meticulous observation of sanitary regulations in the egg powder industry, we are still faced with salmonella infections. This hazard persists even when manufacturing takes place under hygienically ideal conditions.

Dr. H. R. Bird (U.S.A.): Salmonella contamination has also been found in other food products, such as meat and vegetable products.

Dr. H. Westermarck (Finland): There have been outbreaks of salmonella in Finland and Sweden which have lead to the need for sterilization of imported fish meal. This leads to the question as to how meal can be sterilized without impairing its nutritive value.

Dr. A. M. Leroy (France): While sterilization reduces the bacterial count, heat can decrease the biological value of the product. Manufacturers should realize this fact, and use discretion in sterilizing such a product.

Dr. H. R. Bird (U.S.A.): Since fish meal costs are of prime importance to the user, and phosphorus supplements are expensive, advantage should be taken of the natural minerals in the meal.

Dr. L. E. Ousterhout (U.S.A.): There is no known way to sterilize fish meal without impairing its protein quality.

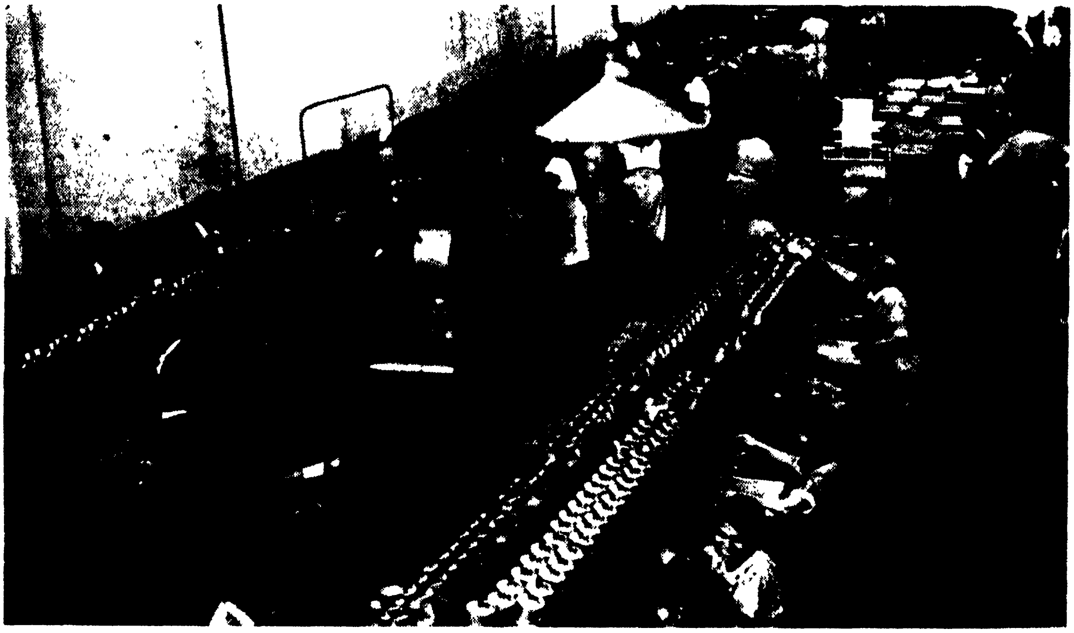
Dr. A. M. Leroy (France): Fish meal should be evaluated in terms of digestible protein and amino acid values, and less emphasis should be given to the vitamin and mineral values.

Dr. H. Westermarck (Finland): The detection of salmonella in fish meals is not easily accomplished.

Dr. H. L. A. Tarr (Canada): There is the possibility of using gaseous chemical disinfectants.

Dr. D. G. Snyder (U.S.A.): Sterilization is not necessary, if proper processing methods are used.

Dr. H. L. A. Tarr (Canada): The contamination of fish meal is due to vermin and rats which find their way into the meal during transportation and storage.



South American countries of Chile and Peru have developed rapidly in fishing enterprise in recent years particularly in canning and fish meal output. FAO has given much technical assistance in both fields. Picture shows the interior of a canning factory in Chile. The production of Peruvian fish meal in particular has reached spectacular dimensions owing to the plentitude of fish and good climatic conditions permitting efficient and economical production.

FISH AND FISHERY PRODUCTS IN RUMINANT NUTRITION

by

A. EKERN, T. HOMB, H. HVIDSTEN, O. ULVESLI, and K. BREIREM

In Norway considerable quantities of fish meal, especially herring meal, have been produced over many years. As this fish meal has been sold at prices competitive with those of oil seed meals, fish meal as a feed for ruminants has for a long time aroused a great interest. On account of the good results attained by using herring meal to supplement poor rations, the farmers now have great confidence in herring meal. Hence they often request that feed mixtures for ruminants should contain herring meal.

In Norwegian experiments, with about 450 dairy cows, varieties of fish meal have been compared with oil seed meals. By the use of poor rations, made up of low-quality roughage, a response to herring meal has been established in the milk yield. In more recent experiments, in which better-quality forages and balanced rations have been supplied, it was not possible to confirm that herring meal raises the milk yield.

In two of the experiments, however, the herring meal raised the content of milk protein significantly.

In corresponding experiments with young cattle, herring meal gave higher live weight gains than did oil seed meal.

In the feeding of sheep and goats, fish meal has proved to be of great value as a supplement to roughage rations.

Finally, fish meal, and especially better-quality herring meal, seems to be acceptable to ruminants, and may replace oil seed meal according to their contents of digestible protein.

When poor-quality rations are supplemented, the high content of minerals and vitamin D (herring meal) of the fish meal may be a valuable asset.

LES PRODUITS DE LA PECHE DANS L'ALIMENTATION DES RUMINANTS

En Norvège, on a produit durant de nombreuses années des quantités considérables de farines de poisson, notamment de farine de hareng. Comme ces farines étaient vendues à des prix compétitifs de ceux des farines de tourteaux d'oléagineux, elles ont éveillé un grand intérêt pour l'alimentation des ruminants. Grâce aux bons résultats obtenus par la supplémentation des rations pauvres avec de la farine de hareng, les fermiers ont acquis une grande confiance en celle-ci. Aussi demandent-ils souvent que les mélanges alimentaires pour ruminants contiennent de la farine de hareng.

Dans des expériences norvégiennes, on a comparé, pour 450 vaches laitières environ, diverses farines de poisson avec des farines de tourteaux d'oléagineux. En utilisant les rations les plus extrêmes composées d'issues de faible valeur alimentaire, on a pu établir l'effet de la farine de hareng sur la production de lait. Dans des expériences plus récentes avec des fourrages de meilleure qualité et des rations équilibrées, il n'a pas été possible de confirmer que la farine de hareng élevait la production du lait.

Dans deux de ces expériences, cependant, la farine de hareng élevait notablement la teneur en protéines du lait.

Dans des expériences parallèles sur du bétail jeune, la farine de hareng amenait des gains de poids supérieurs à ceux obtenus avec les farines de tourteaux d'oléagineux.

Dans l'alimentation des moutons et des chèvres, les farines de poisson se sont révélées de grande valeur pour la supplémentation des rations d'issues.

En conclusion, les farines de poisson (et notamment les meilleures qualités de farines de hareng) semblent convenir aux ruminants et peuvent remplacer les farines de tourteaux d'oléagineux en raison de leur teneur en protéines digestibles.

Dans la supplémentation des rations de mauvaise qualité, la haute teneur en minéraux et en vitamine D (farine de hareng) des farines de poisson peut jouer un rôle appréciable.

EL PESCADO Y LOS PRODUCTOS PESQUEROS EN LA ALIMENTACION DE RUMIANTES

En Noruega, desde hace muchos años se fabrican cantidades ingentes de harina de pescado, particularmente de arenque. Como las harinas de pescado se han vendido a precios de concurrencia con las de semillas oleaginosas, su empleo como pienso para rumiantes causa gran interés desde hace mucho tiempo. Debido a los buenos resultados obtenidos con el empleo de harina de arenque como complemento de raciones deficientes, los ganaderos tienen gran confianza en ella y requieren con frecuencia que las mezclas de piensos para rumiantes las contengan.

En experimentos realizados en Noruega con 450 vacas lecheras, se hicieron comparaciones entre varias harinas de pescado y de semillas oleaginosas. Empleando raciones pobres, formadas por forraje de gran volumen, pero de baja calidad, se ha demostrado que la adición de harina de pescado incrementa el rendimiento de leche. En otros experimentos llevados a cabo más recientemente, en los que se emplearon forrajes de mejor calidad y raciones equilibradas, no se logró confirmar que la adición de harina de pescado dilatase la producción de leche. Sin embargo, en dos de las experiencias con harina de arenque aumentó sensiblemente el contenido proteínico de la leche.

En experimentos correspondientes con ganado joven, pesó más en pie el alimentado con harina de arenque que el que recibió harinas de semillas oleaginosas.

En la alimentación de ovejas y cabras, las harinas de pescado tuvieron gran valor como complementos de las raciones de forrajes de gran volumen.

Finalmente, las harinas de pescado, particularmente las de arenque de mejor calidad, parecen aceptarlas los rumiantes y, de acuerdo con su contenido de proteína digestible, pueden llegar a substituir a las de semillas oleaginosas.

Cuando a las raciones de mala calidad se adicionan harinas de pescado, el elevado contenido de minerales y vitamina D (harina de arenque) de éstas puede dar excelentes resultados.

IN 1884, a factory for production of herring oil and herring meal was erected in Norway by an English firm. Ten years later, in 1894, the first Norwegian factory was built. Today in Norway we have 70–80 factories for production of herring oil and herring meal.

Herring meal is by far the most important fish meal in this country. For the years 1951–55, the average production was 190,000 metric tons. The quantity, however, varies greatly from year to year, depending upon the catch of herring. Up to 1957, Norway was second only to the U.S.A. in production of fish meal, but later both Peru and Japan have by-passed Norway.

Since 1858, a fish meal made from air-dried heads and backbones of codfish has been produced in Norway, and exported as a fertilizer (guano). Some decades later, in the 1890s, in Germany this product was found to be very well suited for supplementing grain and potatoes in the feeding of pigs. During the years 1911–15 most of the production (12,600 tons) was exported. Since then, the production of air-dried fish meal has been decreasing. On the other hand, there has been a great increase in production of dehydrated, white fish meal, a by-product (about 50 per cent of the fish) from the production of frozen fish fillets. In the years 1955–56, about 18,000 metric tons of white fish meal were produced in Norway. Three-fourths of this quantity was dehydrated (31).

Although the whale is not a fish, whale meal, in the opinion of animal nutritionists, shows similarities to fish meal. The Norwegian catch of whale in the Southern Arctic aims mainly at producing whale oil. It has only to a small extent been possible to utilize the rest of the carcass for production of whale meat. From an economic standpoint it is not feasible as a rule to manufacture whale meal on board a ship, and then to transport this intrinsically low-priced product over enormous distances.

In Norway, as in every other developed country, fish meal and other animal feeds are considered to be of greatest value for single-stomach animals. However, since herring meal has often been comparatively cheap in Norway, the use of fish meal for ruminants also, especially dairy cows, has aroused some interest. Accordingly, there has been a great demand for research on fish meals for ruminants in Norway. In fact, the first feeding experiment in Norway, carried out in 1892–93, by the aid of special funds raised by the Norwegian Parliament, was concerned with a comparison of oilseed meal, herring meal, and whale meal (see later).

Composition and digestibility of fish meal and whale meal

The composition of representative samples of Norwegian fish meal is given in this table.

	Dry matter %	*Crude protein* %	*Ether extr.* %	*Ash* %	*Ca* %	*P* %
Herring meal	91	71 (71–73)	8 (6–8)	9	2·0	1·8
Air-dried fish meal	89	50	1	35	9·5	5·0
Dehydr. whole fish meal (haddock)	92	74	4	14	3·9	2·4
Whale meal (whale meat meal)	91	82	4	5	0·6	0·7
Whale feed meal (with bones)	92	65	3	22	6·1	3·1

The coefficients of digestibility, determined in sheep in Norway, are given in the following table.

	No. of experiments	*Protein*	*Ether extr.*	
Herring meal	20	91	95	
Air-dried fish meal	8	89	96	
Dehydr. whole fish meal	3	95	96	
Whale meal (meat meal)	5	95	100	Vacuum-drying
Whale meal (meat meal)	3	82	100	Ordinary drying
Whale feed meal	4	79	100	Ordinary drying

As for digestibility, it should be mentioned that most Norwegian fish meals are dried directly with fire gases (flame drying). It has been demonstrated that, when overheating is avoided, this drying method, as practised in the experienced Norwegian factories, has no adverse effects on protein quality, either in respect of digestibility or of biological value. In extensive studies in pigs, comprising growth experiments, as well as nitrogen balance experiments, Homb and Homb *et al.* (14, 15) thus found that flame-dried herring meal was about equal to steam-dried herring meal.

The great differences in digestibility, however, between the three whale meals in the table above, are certainly caused by overheating of the second and the third meals. The drying method may thus affect the digestibility to a considerable extent. Whale meal of comparable quality with those mentioned above have also been tested in Swiss experiments with rats (28). In the same order as used in the table above, the true digestibility of protein in the three types of whale meal was 98, 79, and 82: the corresponding figures for the calculated biological value were 74, 51 and 46.

Feeding experiments with dairy cows

As stated above, in 1892–93 an experiment was carried out to compare whale meal and herring meal with a mixture of linseed meal and rapeseed meal (30). The experiment was conducted according to the design for the Danish type of group experiments. Twenty cows were divided into two groups, and two experimental periods were used. In the first, whale meal was used, and in the second herring meal. The fat content and the average quantities of the two meals used were as follows:

	Fat content %	*Daily quantity fed* kg.
Whale meal	28·8	1–1·5
Herring meal	14·3	1–1·5

The effect of the whale meal on the yield was:

	kg. of milk		*Fat percentage*	
Group	*Control (oil seed meal)*	*Exp. (whale meal)*	*Control (oil seed meal)*	*Exp. (whale meal)*
Preliminary period, 30 days	9·1	9·1	3·36	3·50
Experimental period, 30 days	7·7	8·3	3·49	3·47
Change	−1·4	−0·8	+0·13	−0·03
Response to whale meal		+0·6		−0·16

The whale meal decreased the fat percentage, but this effect was more than counteracted by the increasing effect on the milk yield. An investigation of the butter quality

	kg. milk per day		*Fat %*		*kg. of F.C.M. per day*		*Live weight kg.*	
Group	*Control*	*Exp.*	*Control*	*Exp.*	*Control*	*Exp.*	*Control*	*Exp.*
Preliminary period, 26 days	11·6	11·5	3·46	3·53	10·66	10·69	425	428
Experimental period, 39 days	10·2	10·7	3·52	3·48	9·47	9·87	431	434
Change	−1·4	−0·8	+0·06	−0·05	−1·19	−0·82	+6	+6
Response to herring meal		+0·6		−0·11		+0·37		±0

revealed no deleterious effects from whale meal or from herring meal.

During the years 1911–14, Isaachsen *et al.* (20), carried out group experiments with 32 cows, and period experiments with 23 cows, to compare cottonseed meal and cod liver meal (31·4 per cent fat). In the group experiment 1·28 kg. of cottonseed meal was replaced by 1·04 kg. of cod liver meal on the average per day. The effect on the yield is shown below:

	kg. of milk per day		*Fat percentage*	
	Control (cotton seed oil meal)	*Exp. (cod liver meal)*	*Control (cotton seed oil meal)*	*Exp. (cod liver meal)*
Preliminary period, 30 days	11·3	11·7	3·40	3·35
Experimental period, 50 days	10·1	10·5	3·45	3·05
Change	−1·2	−1·2	+0·05	−0·30
Response to cod liver meal		±0		−0·35

The cod liver meal reduced the fat percentage by 0·35 units, while the milk yield was not affected. A similar decrease in the content of fat of the milk was noted in the period experiments. The feeding of the fat-rich cod liver meal did not influence the quality of the milk. The butter, however, became soft and oily, although without having any distinctly fishy flavour.

When the fat content of the cod liver meal was reduced to 8·3 per cent, by extraction, Isaachsen *et al.* (19) found only a small decrease in the fat content of the milk (−0·05). This was demonstrated in group experiments with 42 cows. An average daily quantity of 1·2 kg. of groundnut meal was replaced by 1·2 kg. of extracted cod liver meal. It is, therefore, clear that the reducing effect on the fat percentage of the milk could be accounted for by the fat content (cod liver oil) of the meal.

In two series of group feeding experiments, carried out in 1920–21, with 20 and 32 cows respectively (24), two types of air-dried, bone-rich white fish meal containing 5·9 and 1·8 per cent of fat, were compared with cottonseed meal. 0·5 and 0·9 kg. of cottonseed meal was replaced by 0·75 and 1 kg. of fish meal respectively. The response in milk yield to fish meal, calculated on the basis of the changes from the preliminary to the experimental periods, in the same way as in the tables above, was as follows:

	kg. of milk	*Fat %*	*kg. of F.C.M.*
Series 1	+0·41	+0·05	+0·52
Series 2	−0·47	−0·01	−0·43

As mentioned previously, herring meal is the most important fish meal in Norway. Accordingly, the greatest number of experiments has been carried out with this meal.

In a group experiment with 20 cows Isaachsen *et al.* (22) compared herring meal with cottonseed meal. No difference in milk yield was found, but the differences in live weight were slightly in favour of the herring meal.

In 1919–20 (23), herring meal (11·3 per cent fat) was compared with groundnut meal (8·4 per cent fat) in comprehensive group experiments with 74 cows, divided into two groups (paired feeding). The average daily quantity of herring meal during the experimental period was 1·13 to 1·16 kg. of groundnut meal (control group). The effect on the yield is shown in the table above.

The small change in fat percentage was more than counteracted by the increase in milk yield. During the same years a salt-rich herring meal (8·3 per cent fat and 8–10 per cent NaCl) was compared with groundnut meal (12·2 per cent fat) in a group experiment with 20 cows. 0·7 kg. of groundnut meal was replaced by 0·85 kg. of herring meal, in the experimental group. The response to herring meal, calculated as shown above, was as follows:

kg. of milk	*Fat percentage*	*kg. of F.C.M.*	*Live weight kg.*
+0·2	−0·03	+0·12	+3

In another group experiment, with 20 cows, also divided into two groups, ordinary herring meal was compared with salt-rich herring meal. The two types of herring meal were nearly equal in their effect on the milk yield.

In two experiments, comprising 33 cows, 2 kg. of salted herring (9·1 per cent fat) was replaced by 0·5–0·6 kg. of herring meal (9·5 per cent fat) + 0·2–0·3 kg. of maize meal (Isaachsen *et al.*, 1922). The milk yield was not altered, but the fat percentage was somewhat lower for salted herring.

During most of World War II, 1940–45, herring meal was the only protein concentrate available in Norway. Wood cellulose and herring meal were used as substitutes for ordinary grain mixtures. The results attained by this feeding were as a rule satisfactory. As the frequency of ketosis and tetany rose during the war, however, this was naturally ascribed to the cellulose feeding. Experiments were therefore started with war-time rations in comparison with ordinary rations (2).

The war-time rations were made up of small quantities of hay, straw, and roots, with up to 6 kg. of cellulose and

2 kg. of herring meal. In the last experiment, cellulose and herring meal supplied 74 per cent of the estimated net energy requirements, and 90 per cent of the requirements for digestible protein, during the winter season. In 12 cows on this war-time feeding there were no signs of ketosis, whereas ketosis symptoms were noted in 4 out of 12 cows on ordinary feeding. However, hypomagnesaemia and one case of tetany occurred in the cows on the cellulose-herring meal feeding. This experiment seems to be the first in which hypomagnesaemia has been produced in dairy cows. The apparent cause was the low intake of magnesium, 8–10 g. a day to 20–25 g. at ordinary feeding. A magnesium supplement, therefore, proved to be well founded for improving the poor war-time rations.

In later years the justification for continuing the use of fish meal in ruminant feeding has been discussed. Import of oil seed meal for dairy cows and export of fish meal for supplementing all vegetable rations for pigs and poultry used abroad have been advocated. The farmers complained of this program, having great confidence in herring meal for ruminant feeding. The extensive research work since about 1920, mentioned above, seemed to support the farmers' view. It should, however, be remembered that conditions have changed greatly for the better during the last 30–40 years. Earlier harvesting of grassland crops and the introduction of reliable ensiling methods have greatly improved the forage quality. Further, introduction of standardized feed mixtures and mineral mixtures have made it easier to achieve balanced feeding. It was, therefore, deemed necessary to carry out a new series of experiments with dairy cows where these factors were taken into consideration (7).

In these experiments concentrate mixtures with and without herring meal were compared. The composition of the mixtures is shown here:

Mixture	*D I*	*D II*	*A I*	*A II*
% dig. crude protein	40	40	15	15
Herring meal	30	0	10	0
Oil seed meal	44	96	2	18
Grain products	26	4	88	82

In the experimental period mixtures D I and A I were replaced by D II and A II in the experimental group. The basic rations made up of hay, grass silage, alkali-treated straw and roots, supplied about 7 feed units a day.

The daily quantity of herring meal was about 0·5 kg. per day, supplying about one-fourth of the daily protein intake, or more than two-fifths of the protein supplied in the concentrates.

Three experiments were carried out with 66 individually-fed cows divided into two groups. The experiments lasted about 20 weeks and were divided into a preliminary period (6 weeks), an experimental period (10 weeks), and an after period (4 weeks).

The responses to herring meal, calculated on the basis of the differences between the daily yield during the experimental period, and the average daily yield for the preliminary and the after periods are shown thus:

	Response to herring meal kg. of F.C.M. per day
Experiment 1	−0·20
Experiment 2	−0·19
Experiment 3	−0·26
Average	−0·22

The experiments gave very consistent results. Feed mixtures containing herring meal gave a slight decrease in milk yield, but this response was not significant, not even when all three experiments are calculated together ($0·1 > P > 0·05$). It is therefore concluded that herring meal and oil seed meal can replace each other in grain mixtures for dairy cows, according to the content of digestible protein. In the last two experiments, the groups were subdivided with respect to intake of protein. The levels of production feed were 45 and 60 g. respectively, of digestible protein per kg. of F.C.M. At the lower level there was no difference in yield at all between groups which were fed mixtures with and without herring meal.

The fat content of the milk was not changed by the use of herring meal (+0·01 per cent). In two of the experiments, however, a significant increase was found in the protein content of the milk (+1·9 g. per kg. milk), but this was not the case in the third experiment which was carried out on another farm.

In the second experiment, organoleptic judgements throughout the experiment showed no differences in the milk quality as regards oxidation and feed flavour that could be ascribed to the feeding of herring meal.

The results obtained are in good agreement with the findings of Hvidsten *et al.* (18), which show that herring meal fed to dairy cows had no significant effect on the development of oxidized flavour in milk.

The content of polyenoic, fatty acids in the milk fat was studied in experiments 2 and 3 with the kind collaboration of Professor Notevarp at the Norwegian College of Technology. The results of the determinations are given below in per cent (on weight basis):

	Indoor feeding		
	Herring meal	*Oil seed meal*	*Pasture*
Hexaenoic	0·24	0·12	0·06
Pentaenoic	0·25	0·19	0·16
Tetraenoic	0·16	0·17	0·18
Trienoic, unconjugated	0·68	0·71	0·96
Trienoic, conjugated	0·04	0·04	0·06
Dienoic, unconjugated	1·28	1·36	1·27
Dienoic, conjugated	0·75	0·73	1·31
Total polyenoic acids	3·40	3·32	4·00

The contents of hexaenoic and pentaenoic fatty acids were increased by the feeding of herring meal. Otherwise, the experiments confirmed the well-known fact that the

Feed mixtures	*% serum-Ca* *Control*	*% serum-Ca* *Cod liver oil*	*% ash in fat-free dry matter in bone (Atlas)* *Control*	*% ash in fat-free dry matter in bone (Atlas)* *Cod liver oil*	*Gain in live weight g. per day* *Control*	*Gain in live weight g. per day* *Cod liver oil*
Experiment 1. No herring meal	8·0	10·6	47·9	51·1	649	745
Experiment 2. 15% of herring meal	10·8	10·6	54·9	54·3	865	864

content of polyenoic acids of the milk fat in ruminants is only to a very slight extent affected by the feeding.

Feeding experiments with young cattle

In order to supplement feeding experiments with dairy cows, Ekern is also carrying out five experiments with young cattle, from 1 to 1½ years old. The experiments are still in progress, and only preliminary results are available. Ninety-six animals, divided into two groups, are used. In the experimental group 0·2–0·4 kg. of herring meal has been used every day as sole protein concentrate, while 0·3–0·6 kg. of oil seed meal mixture has been fed to the control group. Different basic rations are used. The feed intake has been equalized with respect to net energy, digestible protein, and minerals. The protein intake has been kept at a moderate level. The results, as regards live weight gains, are given here:

	g. weight gain per day *Oil seed meal*	*g. weight gain per day* *Herring meal*
Experiment No. 1	722 (100)	831 (115)
Experiment No. 2	706 (100)	745 (106)
Experiment No. 3	1073 (100)	1167 (109)
Experiment No. 4	789 (100)	859 (109)
Experiment No. 5	539 (100)	603 (112)

A response in live weight gain has been obtained in all experiments. The difference is significant, calculated on the basis of all experiments $(0{\cdot}01 > P > 0{\cdot}001)$.

In Experiment 4, two different rations have been used. There was some difference in response in live weight gain:

	kg. per day		*g. weight gain per day*	
			Supplemented with	
Basal ration	*Oil seed meal*	*Herring meal*	*Oil seed meal*	*Herring meal*
Hay and treated straw	0·60	0·41	793 (100)	881 (111)
Hay, treated straw, and silage	0·26	0·18	785 (100)	835 (106)

The liberal quantity of herring meal required to supplement poor rations seems more effective than the small quantity needed for better rations. In this connection it should be mentioned that the basic rations were rather poor, especially in Experiment 1.

According to these experiments there seems to be no doubt that herring meal increases the growth rate in young cattle. We are unable as yet to explain this effect. Economic reasons all but prohibit the use of amino acid supplements for cattle. Later it may be possible to carry out rumen studies. We have initiated studies of the serum protein, but they have not advanced so far that any results are available.

In an experiment on A and D supplements for young calves, Hvidsten (17) obtained no response to D supplements in calves receiving 15 per cent herring meal in the grain mixture (115 g. of herring meal per day). Since herring meal supplied 460 I.U. of vitamin D per day, there was no need for any further supplementation. Some observations from these experiments are shown in the above table.

Feeding experiments with sheep and goats

In Norway herring meal has been widely used to supplement feed rations for sheep and goats. The farmers are convinced of the great value of herring meal in the feeding of these animals. This opinion is very often based on experiences gained by using herring meal to supplement poor rations, deficient in energy and protein, as well as in other nutrients. Herring meal has thus proved a valuable supplement for sheep on winter pasture (heather and other plants) of low nutritive value. It is evident that under these conditions, concentrates other than herring meal also would do very well, especially when mineral supplements also are used.

We have not yet been able to start studies comprising systematic comparisons of herring meal and oil seed meals, like those with cattle, mentioned above.

From a series of lamb feeding experiments (16) the following results may give an idea of the value of herring meal as supplements to plant rations:

		Intake				
Basal rations	*Supplement*	*Feed units*	*g. dig. protein*	*Gain in live-weight per day g.*	*Wool fibre diameter μ*	*N-balance g/day*
Hay, silage, roots	None	0·50	52	8	28·5	+2·72
Hay, silage, roots	35 g. of herring meal	0·54	71	39	30·3	+4·32
Hay, silage, roots	40 g. of barley meal	0·53	53	18	28·9	+2·87
Hay, silage, treated straw	35 g. of herring meal	0·47	40	41	30·0	+0·99

The small quantity of herring meal (1¼ ounce a day) has greatly improved the performance of the rations as to live weight gain. The cause of the apparent discrepancy between live weight gain and N-balance in the last group may be a high water intake with a corresponding high urine quantity. It is a common experience that treated straw leads to an increase in water intake, and it is perhaps necessary to use more long-lasting preliminary periods than usual, in balance experiments with such feeds. The wool fibre diameter in the two groups supplemented with herring meal was significantly higher than that in the first group, calculated on the basis of the differences between autumn and spring wool. These findings are in line with the experiences gained by sheep farmers in Norway, that feeding of herring or fish products during winter season gives good responses in the wool production in sheep.

Discussion

In a number of Norwegian experiments with ruminants, fish meal has proved a valuable feed in supplementing rations made up of straw, hay, silage, and roots. In some old experiments with dairy cows, replacement of oil seed meals by herring meal has been shown to raise the milk yield. It should be taken into consideration that in these experiments the cows were fed on hay left standing out a long time and that the rations used have been somewhat poor and none too well balanced, especially in respect of substances other than protein. In more recent experiments, in which hay and silage of early-cut grass and well-balanced rations were used, it was not possible to confirm that grain mixtures with herring meal give higher milk yield than grain mixtures with oil seed meals fed as sole protein concentrates. However, in two experiments, the herring meal significantly increased the content of milk protein.

In young cattle fed on different well-balanced basic rations, the replacement of oil seed meal by herring meal led to a significant increase in live weight gain.

Herring meal and other fish meal of high quality should undoubtedly be classified as valuable protein concentrates for ruminants. They may replace other protein concentrates, according to their contents of digestible protein. The high content of some minerals, especially Ca, P, Na, Cl, I, and vitamin D (herring meal) may be an asset, especially in supplementing poor rations.

It is doubtful whether the high protein quality of fish meals is of any special value. As stated above, herring meal has been found to raise the protein content of milk, and it has further proved most effective when the protein intake is kept at a low level. When liberal quantities were fed, it was not possible in Danish experiments to find any response in live weight gain to herring meal replacing oil seed meals in the feeding of young calves (8).

It has been indicated (25) that high-quality protein may possibly give a response above the level at which the rumen microbes are able to synthesize protein even in ruminants. Our experiments neither prove nor disprove this hypothesis.

Experiments by Chalmer, Synge, and Marshall (3, 4, 5) have demonstrated that protein in herring meal may be better utilized in the ruminant than protein in oil seed meal and that this can be ascribed to the fact that herring meal protein is more resistant to degradation in the rumen. We have not been able to carry out more than preliminary observations on the protein degradation in the rumen. In recent work on young calves at Rowett (Whitelaw *et al.* (33)) live-weight gain as well as nitrogen retention was significantly higher on fish-meal diet than on isonitrogenous groundnut diets. Differences were also found in urinary nitrogen losses and blood urea concentration. The solubility for nitrogen was much lower in fish meal than in groundnut meal. On the basis of existing experiments, Blaxter (1) does not consider it likely that there are significant differences in biological value of proteins in ruminants, like those demonstrated in single-stomach animals.

The marine fats in certain fish meals have been found to reduce the fat percentage of milk in proportion to the quantity of fat fed. The experiments by Isaachsen and associates in Norway seem to be the first experiments in which the fat-reducing effect of cod liver oil has been demonstrated. Later, this effect has been confirmed by many, especially by English and American investigators (9, 10, 11, 26, 29). Recently, Shaw (32) demonstrated that cod liver oil lowers the proportion of acetic acid in the volatile fatty acids in the rumen. He thereby offered an acceptable explanation of the decreasing effect of the cod liver oil on the fat percentage.

It should be noted that in our experiments on herring meal the fat percentage of the milk has been affected only to a very small extent, at levels of about 1 kg. of herring meal a day, and not at all at about 0·5 kg. It should then be taken into account that during storage the fat in herring meal is mildly oxidized, the iodine number of the herring meal fat being 70–90 to about 140 in genuine herring oil.

In our experiments we have no parallel to the powerful effect of cod liver oil fed to dairy cows on the composition of milk fat as demonstrated by Hilditch *et al.* (13). It seems, in our experiments, that milk fat, as well as body fat in cattle, is rather resistant as far as the influence of feeding is concerned.

On the request of Dr. Dahl, Malmö, Sweden, we fed herring meal and oil seed meal for several weeks to two cows which were to be slaughtered. It was not possible to demonstrate that the polyenoic fatty acids, characteristic of herring meal, were transferred to body fat (6).

The good results attained by using herring meal as a supplement in the feeding of sheep have been confirmed in experiments carried out in Iceland (12, 27).

As to the acceptability of fish meal to ruminants, only very slight difficulties are encountered with herring meal, even when it is fed as sole concentrate. Some time may be needed to get the animals accustomed to herring meal;

and some animals, one in twenty or more, may refuse to take herring meal when not mixed up with other concentrates.

Practical experience has shown that the slightly brown herring meals are preferred. While the herring meal is acceptable, the air-dried, bone-rich fish meal is less suited for ruminants, as many animals refuse to eat it.

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DISCUSSION

On the paper submitted by Dr. K. Breirem and his colleagues, **Dr. J. Kielanowski** (Poland) remarked: Unpublished data obtained by Czaja in Poland seem to show that high-producing cows, yielding more than 25 kg. milk per day, respond more favourably to high quality fish meal than to other concentrates containing a similar amount of protein with a lower biological value. It has been reported that the growth of calves is increased, when they are fed on "starter" preparations containing fish meal. These results are more of a theoretical than of a practical interest, since fish meal certainly can be fed more profitably to pigs and to poultry than to ruminants.

Dr. I. W. McDonald (Australia): Contrary to some opinions expressed in these meetings, the ocean is *not* the last frontier for high quality protein production. Agriculture can produce a lot more high quality protein than it is supplying at present. Dr. Kesteven pointed out that knowledge of ocean ecology is too incomplete to permit predictions of its potential production of high quality protein. But the ecology of pastures also is not too well known. Of all farm animals, the ruminant is the least exacting as to the quality of protein required, and the least competitive with man in nutrient requirements. We must place ruminants in proper perspective in regard to production of food for man, and keep in mind the fact that, with a rising standard of living, people tend to eat less fish and more meat.

Dr. M. A. Raafat (U.A.R.): Cottonseed cake is much less expensive in Egypt than fish meal, and therefore the former is used for ruminant feeding. Poultry production is still limited in our country, and therefore our fish meal consumption per capita is not great.

Dr. G. Borgström (U.S.A.): The comments made by Dr. McDonald lead me to observe that the biomass of livestock corresponds in terms of consumption of protein to almost 13 billion humans of average size (70 kg.). This includes draught animals required for present day food production. Cattle represent approximately 10 billion, pigs, 1·3 billion, and poultry about 650 billion. While the ideas expressed by Prof. Breirem are undeniably correct, it should be kept in mind that ruminants constitute a "beach-head" in the plant kingdom, because they utilize celluloses and other organic compounds that man cannot digest. The gap between the "haves" and the "have-nots" becomes wider, when we consider the relative consumption of animal products. Only one-tenth of the world's food intake is of animal origin. In terms of consumed protein, however, one-third is represented by animal protein. But more than 50 per cent of this protein is eaten by less than 500 million people. We are using an overwhelming proportion of world resources to feed a minority of the world's people; most humans are vegetarians, not by choice, but by force of circumstances. There is no argument with the viewpoints presented by Prof. Breirem and others, that the use of fish meal contributes toward greater efficiency in ruminant and other animal nutrition. Such conversion should be strongly endorsed, but should not reduce the efforts to accomplish a better direct use by humans of all fish resources. As things now stand, the poultry, pigs, and cattle of the well-fed nations may be thought of as depriving the malnourished millions of this high quality protein indispensable for their well being. This is a challenge for food technology.

DR. J. C. SHAW (FAO): In the near future, perhaps all the available fish oil will be used to control rumen fermentation in the production of both meat and milk, since we now know that certain unsaturated acids can be so used.

Meal and ruminants

Dr. McDonald was asked whether the utilization of protein in the rumen can be increased by control of the type of carbohydrate ingested. He replied: There is considerable scope for increasing the utilization of nitrogen by varying the remainder of the ration. The ruminant depends to a large extent on microorganisms in the rumen to transform inorganic nitrogen and low-grade proteins into the amino acids required by the animal. If microorganisms are present in the rumen with adequate starch and related carbohydrates, the source of nitrogen has little importance. In grains there is plenty of protein for ruminants; but if some cheap source of starch becomes available, inorganic nitrogen can be utilized in meat production.

DR. A. M. LEROY (France): We have been led to believe that the biological value of proteins is unimportant in ruminant nutrition; actually, superior results are obtained with complete proteins.

DR. K. BREIREM (Norway): Nitrogen balance and growth experiments show air-dried herring meal about equal to the steam-dried product.

PROF. H. CABALLERO (Chile): In certain countries, low-cost high-quality protein supplements will always be in demand. For young ruminants, fish meal is valuable in "calf starter" rations; in effect this conserves milk for human consumption, the calf utilizing fish meal instead of milk.

Scientific feeding of pigs (see following article by R. Braude) must include an adequate ration of protein much of which can be well supplied by fish meal. By good feeding this line of pigs has been maintained in health and brought to superb condition.—*Farmer and Stockbreeder photograph.*

Section 2b: PIG NUTRITION

FISH AND FISHERY PRODUCTS IN PIG NUTRITION

by

R. BRAUDE

From time immemorial, fish surplus to human requirements and occasional fish waste have often found their way into the pig trough. From this casual, and often haphazard practice, particularly concentrated in areas bordering the sea, the nutritional value of fish products for pigs has been gradually recognized and scientifically studied.

Industrial exploitation in this field, which started in the second part of the last century, has firmly established fish products as important feedingstuffs. In many parts of the world a large industry has developed which, in addition to the surplus and waste from the human table, uses vast quantities of fish especially caught for this purpose. In the early stages of this development most of the scientific effort was directed towards measuring the quality of the fish products, and proving their nutritional value for different classes of livestock. Once the value was recognized, however, the demand for some of the products began to exceed the supplies, and the current problems are how to control the quality of the available limited supplies and how to use them to the best advantage.

The most important fish product used in pig feeding is fish meal. Fish silage has in the last few decades been used extensively in some countries. Fish oil and fish solubles have their application. Raw fish is used only in very special circumstances.

There exist fish products of very high nutritional value for pigs, but also some devoid of any value at all. Each specific product—one could say each specific consignment—has to be judged on its merits. The overall guiding principles on which to base such judgement have been established, and in some countries quality standards for fish products as animal feedingstuffs have been developed.

The composition of the fish product will determine its application in practical pig rations. Usually fish products are added in relatively small quantities in order to balance the mixture for essential nutrients. The main contribution that fish products can make is by augmenting and improving the protein, mineral and vitamin components of rations. Whether fish products also supply growth factors, as yet unidentified, remains an open and widely-discussed question. The amount of fish products which should be used will depend not only on their own quality, but also on the quality of the ingredients to which they are added; this will also depend on the age and type of pigs to be fed, and on the level of performance expected from them.

Perhaps the most important factor on which the future use of fish products in pig rations depends is the cost of supplementation. Nowadays pig rations can be balanced satisfactorily in many different ways, and the use of fish products for this purpose must be economically competitive with other methods of supplementation.

The full paper will include a critical survey of literature and tabulated data on all subjects mentioned in this brief synopsis.

POISSON ET PRODUITS DU POISSON DANS L'ALIMENTATION DES PORCS

Depuis des siècles, le poisson excédentaire en consommation humaine et les déchets occasionnels de poisson ont souvent trouvé leur destin dans l'auge du porc. Cette pratique occasionnelle et souvent fortuite a permis de reconnaître et d'étudier la valeur nutritive des produits du poisson pour les porcs.

Dans ce domaine, l'exploitation industrielle (qui a débuté dans la deuxième partie du siècle dernier) a fermement établi l'importance alimentaire des produits du poisson. Dans de nombreuses parties du monde, il s'est développé une grande industrie qui utilise, en plus des excédents et déchets de la consommation humaine, de larges quantités de poisson capturées directement à ce but. Dans les premières étapes de son développement, la plus grande part de l'effort scientifique a été dirigée vers la mesure de la qualité des produits du poisson, et vers la définition de leur valeur alimentaire pour différents types de bestiaux. Quand cette valeur était reconnue, la demande pour quelques-uns des produits du poisson commençait à excéder les ressources, et les problèmes courants portent maintenant sur la façon de contrôler la qualité des ressources limitées disponibles et de les utiliser au mieux.

Le produit du poisson le plus important qui soit utilisé dans l'alimentation du porc est la farine de poisson. Le poisson d'ensilage a été largement utilisé au cours des dernières décades dans quelques pays. L'huile de poisson et les solubilisés de poisson ont leurs applications. Le poisson brut n'est utilisé que dans des circonstances très spéciales.

Il existe des produits du poisson de très haute valeur nutritive pour les porcs, mais il en est aussi qui sont sans aucune valeur. Chaque produit spécifique (et, pourrait-on dire, chaque livraison spécifique) doit être jugée selon ses mérites. On a établi les principes guides généraux sur lesquels baser un tel jugement, et dans quelques pays on a défini des normes de qualité pour les produits du poisson destinés à l'alimentation du bétail.

La composition du produit du poisson doit déterminer son application dans les rations pratiques pour les porcs. Habituellement, les produits du poisson sont ajoutés en quantités relativement faibles pour équilibrer dans le mélange les éléments nutritifs essentiels. La contribution principale que peuvent apporter les produits du poisson consiste dans une augmentation et dans une amélioration des composants protéiques, minéraux et vitaminiques des rations. Que les produits du poisson fournissent également des facteurs de croissance non encore identifiés, c'est là une question qui reste ouverte et largement discutée. La quantité des produits du poisson qui doit être utilisés ne dépend pas seulement de leur propre qualité, mais aussi de la qualité des ingrédients auxquels ils sont ajoutés; elle dépend également de l'âge et du type de porcs à nourrir et des performances qu'on attend d'eux.

Il est possible que le facteur les plus important dont dépend l'utilisation future des produits du poisson dans les rations des porcs soit le coût de la supplémentation. Aujourd'hui, les rations pour les porcs peuvent être équilibrées d'une façon satisfaisante de différentes manières, et l'utilisation des produits du poisson à cet effet peut être enfin compétitive sur le plan économique avec les autres méthodes de supplémentation.

L'article complet comprend un examen bibliographique critique et des données chiffrées sur tous les sujets mentionnés dans ce bre exposé.

EL PESCADO Y LOS PRODUCTOS PESQUEROS EN LA ALIMENTACION DE LOS CERDOS

Desde tiempo inmemorial el pescado excedente del consumo humano y los desechos ocasionales de pescado han ido a parar a las gamellas de los cerdos. Esta costumbre ocasional y con frecuencia fortuita, que se da particularmente en lugares próximos al mar, ha permitido reconocer el valor nutritivo de los productos pesqueros en la alimentación de los cerdos.

En este sector, la explotación industrial, que comenzó en la segunda mitad del siglo pasado, ha establecido firmemente los productos pesqueros como un pienso de gran importancia. En muchas partes del mundo se ha creado una gran industria que, además de aprovechar los excedentes y desperdicios del consumo humano, utiliza enormes cantidades de pescado especialmente capturado con esta finalidad. En las primeras etapas de esta innovación, casi todos los esfuerzos científicos se encaminaron a medir la calidad de los productos pesqueros y a demo-

strar su valor nutritivo para diferentes clases de ganado. En cuanto se reconoció el valor, la demanda de algunos productos comenzó a exceder a la oferta, y los problemas actuales son cómo regular la calidad de los limitados suministros de que se dispone y cuál es su mejor uso.

El producto pesquero más importante empleado en la alimentación de cerdos es la harina de pescado. El ensilado de pescado se usa estensamente en las últimas décadas en algunos países. También encuentran aplicación el aceite y solubles de pescado. El pescado bruto se emplea solamente en circunstancias muy especiales.

Existen productos pesqueros de elevado valor nutritivo para los cerdos; pero también hay algunos que no tienen ningún valor. Cada producto específico (o, mejor dicho, cada partida específica) se tiene que juzgar según sus méritos. Se han establecido los principios rectores generales sobre los cuales basar tal juicio, y en algunos países se han formulado normas de calidad para los productos pesqueros destinados a la alimentación de los animales.

La composición de los productos de la pesca determina sus aplicaciones en las raciones prácticas para los cerdos. Habitualmente los productos pesqueros se adicionan en cantidades relativamente pequeñas para equilibrar le mezcla de los elementos nutritivos esenciales. La principal contribución que pueden aportar los productos de la pesca reside en un aumento y en una mejora de los componentes proteicos, minerales y vitamínicos de las raciones. Si los productos pesqueros suministran también factores de crecimiento todavía sin identificar, es una cuestión abierta y largamente discutida. La cantidad de productos pesqueros que deberán usarse no sólo dependerá de su propria calidad, sino dependerá también de la de los ingredientes a los que son adicionados; esto también dependerá de la edad y del tipo de cerdos a ser alimentados, y del rendimiento que se espera de ellos.

Es posible que el factor más importante, del que dependerá el empleo futuro de los productos pesqueros en la alimentación de los cerdos, sea su coste como complemento. Actualmente, las raciones para los cerdos pueden equilibrarse satisfactoriamente de muchas maneras distintas, y el empleo de productos pesqueros con este fin debe ser capaz de contribuir económicamente con otros complementos.

La comunicación completa incluye el examen bibliográfico crítico y tablas de datos relativos a todas la cuestiones mencionadas en este breve resumen.

DURING the last 50 years, reviews and general articles on the subject of fish meal and other fish products as animal feedingstuffs in general and as pig food in particular have been published in different countries: (7, 19, 30, 34, 40, 41, 60, 62, 66, 89, 98, 100, 102, 115, 116, 150, 160, 168, 214, 215, 239, 240).

In pig feeding the aim is to ensure:

(1) Satisfactory reproduction.
(2) Rapid rate of growth.
(3) Efficient utilization of food.
(4) Carcass quality desired by the market which is dictated by the requirements of the consumer.

Although many factors in pig production ultimately determine the results, proper feeding is by far the most important. 70–85 per cent of the total cost of pig production lies in the cost of food. The choice of ingredients for pig rations must be governed by the nutritional requirements of the pigs, and the resulting balanced rations must be economically sound.

In general, the attitude to supplementation of pig rations with fish products, particularly fish meal, is governed to a great extent by the availability of alternative high-protein supplements. In Europe, for example, where the production of these is rather limited, fish meal has become a standard protein supplement, and therefore much attention has been paid to its quality which has progressively improved. In America, on the other hand, where high-protein vegetable supplements are in abundance, fish meal was until recently treated as of secondary importance and its quality received much less attention than, for example, in the United Kingdom or Scandinavian countries.

Variation in composition of fish meal

As there exist innumerable types and varieties of fish, that are procured by very many different methods, and as, moreover, the raw material can be processed in many

TABLE I

Composition of fish meals of different origin (H. Hubbell, 1961)

		Herring	*Menhaden*	*Red fish*	*Sardine*	*Tuna*	*White fish*
Crude protein	%	70·0	60·0	57·0	65·0	62·0	63·0
Ether extract	%	7·0	8·0	8·0	4·0	7·0	2·0
Fibre	%	1·0	1·0	1·0	1·0	1·0	1·0
Ash	%	12·0	20·0	26·0	19·0	20·0	22·0
Ca	%	3·0	5·0	7·7	4·5	4·0	6·5
P	%	2·0	3·0	3·8	2·4	2·5	3·5
Choline	mg./lb.	1,800	1,500	1,400	1,300	1,400	700
Nicotinic acid	mg./lb.	40·0	25·0	18·5	30·0	30·0	30·0
Pantothenic acid	mg./lb.	5·0	4·0	3·0	3·0	4·0	3·0
Riboflavin	mg./lb.	4·0	2·0	3·0	2·5	4·0	4·0
Arginine	%	4·0	4·0	4·0	2·7	5·3	4·2
Lysine	%	6·3	5·3	6·5	5·9	5·2	4·3
Methionine	%	2·0	1·8	1·7	2·0	1·7	1·7
Cystine	%	1·1	1·0	0·6	0·8	1·0	—
Tryptophan	%	0·9	0·7	0·6	0·5	0·7	0·6
Glycine	%	5·0	4·0	3·7	4·5	4·2	—

TABLE II

Variation in composition of fish meal, per cent. (From Bollman (1959) who during the last 5 years has analysed 1,100 samples of fish meal from 18 countries)

	Mean	*Range*
Moisture	8·26	5·5–11·8
Crude protein	57·82	42·3–68·8
Crude fat	6·09	1·8–11·1
Salt	4·09	0·9–15·6
$CaHPO_4$	13·93	9·0–17·9
Sand	2·71	0·3–10·5

different ways, it is obvious that the term "fish products" can only be a general one.

Table I, which gives compositional details of six fish meals of different origin, as given by Hubbell (107), shows clearly that differences in specific nutrient contents may be quite considerable. In products designated by the same name and purporting to be of similar origin, the differences may be of similar or even greater magnitude. In Table II, reproduced from Bollmann (23), mean values and ranges are given for 1,100 samples of fish meal originating from 18 different countries. Woodman and Evans (241–245) in reports of their experiments with pigs gave compositional details of white fish meal employed by them; in Table III calculated means for 38 such consignments are given together with ranges.

TABLE III

Variation in composition of white fish meal, per cent, used in Cambridge experiments by Woodman and Evans. (Samples from 38 consignments)

	Mean	*Range*
Moisturer	11·3	5·7–14·9
Crude potein	62·9	55·0–71·2
Ether extract.	3·6	1·7– 5·9
N-free extract	0·6	0 – 3·2
Ash	22·3	17·2–25·8

Thus in computing practical rations it is of the utmost importance to recognize the fact that values derived from standard tables giving composition of feedingstuff refer to averages, and that the ranges associated with the averages may be very wide.

Control of quality of fish meals

Differences in composition of fish products may be attributed to many causes: variation in the composition of the raw material (including the proportion of whole fish and fish offal and contamination with sea animals other than fish), different methods of processing (including efficiency in removal of fat, heat treatment, etc.), contamination with some waste products or sand, etc.

There exist fish products of very high nutritional value for pigs, but also some devoid of any value. Each specific product, one could say each specific consignment, has to be judged on its merits. The overall guiding principles on which to base such judgement have been established and in some countries quality standards for fish products as animal feedingstuffs have been developed.

About 30 years ago Mach and Claus (155) reported a survey carried out in 22 laboratories in Germany on 1,937 samples of fish meal, and classified 632 of them as objectionable for the following reasons:

1. (1) Not fresh.
2. (2) Sand content (ranging from 5 to 24 per cent instead of up to 1 per cent).
3. (3) Sea-fauna impurities (crabs, crayfish, mussels, etc.).
4. (4) Impurities of animal origin.
5. (5) Excessive salt content (ranging from 5·4 to 13 per cent NaCl).
6. (6) Excess of fat (over 5 per cent).
7. (7) Too high moisture content (above 12 per cent).
8. (8) Wrong description, etc.

Some of these objections might not be considered of major consequence, but the list underlines the importance of controlling the quality of fish meals.

In recent years, in many countries, big efforts have been and are being made to devise means of effectively controlling the quality of animal feedingstuffs, particularly of protein quality in protein-rich supplements. The difficulties with which these efforts are confronted are well summarized in the report just published by Boyne, Carpenter and Woodham (24) under the title "Progress report on an assessment of laboratory procedures suggested as indicators of protein quality in feedingstuffs". This report contains interesting information on fish meal.

At a recent conference in Paris (1961), Professor Leroy summarized the available evidence on the subject, and suggested specific requirements to be fulfilled before a consignment of fish meal is classified as being of good quality.

In Germany, Kummer and von Polheim (141) have subjected 412 samples of fish meal to detailed analysis and classification.

Nutritive value of fish meals

In order to illustrate the value of fish meal as a supplement to pig rations, figures are given in Table IV showing the absolute and percentage contribution made by a definite quantity of fish meal to the nutrient composition of a specific ration. As an example, the Shinfield 7 per cent white fish meal ration was used, the ingredients of which are given in Table V. This ration is intended for growing pigs from 40 to about 120 lb. liveweight, and it covers their conventional requirements for essential nutrients. In the last column of Table IV these requirements are given as stated by the National Research Council (167). It can be seen from this table that this relatively small supplement of fish meal made a decisive contribution by bringing the content of nutrients in the mixture up to the level required. As far as major nutrients are concerned, this mixture without the fish meal would be deficient in crude protein, calcium, phos-

TABLE IV

Detailed composition of ingredients of the Shinfield 7 per cent fish meal ration with contribution of cereals and fish meal to the total nutrient content of the ration contrasted with NRC requirements for a pig weighing 50 lb.

Underlined figures are where fish meal makes an essential contribution

		Content of ingredients			*Content of ration*				
					Contributed by				
		Barley meal	*Fine wheat offal*	*White fish meal*	*Cereals 92%*	*White fish meal 7%*	*Total*	*Percentage of total contributed by fish meal*	*NRC requirement*
Crude protein	%	11·6	15·5	63·2	12·2	4·4	16·6	26·7	15·0
Ether extract	%	1·9	4·2	4·4	2·6	0·3	2·9	10·6	1·5
Fibre	%	5·0	5·0	—	4·6	—	4·6	0	—
Ash	%	2·7	3·9	21·7	2·9	1·5	4·4[1]	34·0	—
Ca	%	0·09	0·08	7·87	0·08	0·55	0·63[1]	87·5	0·65
P	%	0·47	0·74	3·61	0·53	0·25	0·78[2]	32·1	0·50
K	%	0·63	0·80	0·33	0·64	0·03	0·67	4·5	0·28
NaCl	%	0·2	0·12	1·65	0·15	0·12	0·27	44·4	0·50
Mg	%	0·14	0·33	0·10	0·20	0·01	0·21	3·4	0·40
Mn	mg./lb.	8·3	43·0	6·5	20·8	0·5	21·3	2·3	
Fe	mg./lb.	27·0	44·0	254·0	31·3	17·8	49·1	36·3	
Cu	mg./lb.	3·9	8·5	3·8	5·3	0·3	5·6	5·4	
Vitamin A	i.u./lb.						2,250[3]		
Vitamin D	i.u./lb.						560[3]		
Choline	mg./lb.	526	447	1,400	454	98	552	17·8	400
Folic acid	mg./lb.	0·28	0·4	0·5	0·3	0·04	0·34	11·7	
Nicotinic acid	mg./lb.	29·3	55·4	25·4	36·9[4]	1·8	38·7	4·6	6·0
Pantothenic acid	mg./lb.	3·3	9·4	4·0	5·4	0·3	5·7	5·0	5·0
Pyridoxine	mg./lb.	1·5	8·0	2·5	3·85	0·17	4·0	4·2	0·5
Riboflavin	mg./lb.	1·0	1·3	2·2	1·03	0·16	1·19	13·4	1·2
Thiamine	mg./lb.	2·6	7·8	0·3	4·37	0·02	4·39	4·6	0·5
Vitamin B_{12}	g./lb.	—	—	60	—	4·2	4·2	100·0	5·0
Arginine	%	0·6	1·0	4·0	0·70	0·28	0·98	28·6	0·2
Histidine	%	0·3	0·4	1·6	0·31	0·12	0·43	27·9	0·2
Isoleucine	%	0·6	0·7	4·1	0·59	0·29	0·88	33·0	0·6
Leucine	%	0·9	1·1	5·0	0·90	0·35	1·25	28·0	0·6
Lysine	%	0·6	0·6	5·5	0·55	0·39	0·94	41·5	0·65
Methionine	%	0·2	0·1	1·8	0·15	0·12	0·27	44·4	0·6[5]
Cystine	%	0·2	0·3	1·2	0·22	0·09	0·31	29·0	
Phenylalanine	%	0·7	0·5	2·7	0·57	0·19	0·76	25·0	0·5
Threonine	%	0·4	0·5	2·9	0·41	0·20	0·61	32·8	0·4
Tryptophan	%	0·2	0·2	0·6	0·18	0·05	0·23	21·7	0·2
Valine	%	0·7	0·7	3·6	0·64	0·26	0·90	28·9	0·4

[1] Limestone not included in the calculation.
[2] As Ca has to be added, the P in fish meal helps to keep the Ca : P ratio right.
[3] Supplied by adding vitamin A and D supplement.
[4] Nicotinic acid in cereals is known to be not available to pigs.
[5] Cystine can replace half of the requirement for methionine.

phorus and salt. This fish meal supplement also made an important contribution to the content of some of the vitamins (B_{12}, riboflavin, nicotinic acid and pantothenic acid). Its most striking and perhaps most important contribution is towards the essential amino acid content of the ration. At least 25 per cent of the total content in the ration of each amino acid was supplied by the 7 per cent fish meal supplement, and with some the contribution exceeded 40 per cent of the total. Incidentally, it is interesting to note that, though the protein content of different fish meals may vary considerably, their amino acid content, when expressed as percentage of protein, varies little, and that Evans (74, 75) has shown no advantage from supplementation of a 7 per cent white fish meal ration with either 0·1 per cent l-lysine or 0·2 per cent commercial lysine. Puchal, Jones, Hayes and Speer (190) studied the utilization of various proteins by the baby pig as measured by performance and blood amino acid patterns, and suggested that the most limiting

TABLE V

Composition of Shinfield, 7 per cent fish meal ration for pigs, per cent

Barley meal	54
Fine wheat offals	38
White fish meal	7
Limestone	1
Vitamins A and D supplement	+

amino acids of fish meal are phenylalanine and isoleucine.

As far as the vitamins are concerned, it is generally accepted that vitamins A and D must be provided as a separate supplement to rations of growing pigs. Fish meal may supply some, but their content of vitamins A and D is usually low and very variable. Scheunert *et al.* (205) have rightly pointed out that with rations otherwise devoid of these vitamins the small contribution made by fish meal may be important.

TABLE VI

Vitamin B potencies (g./g.) of average samples of white fish meal produced in bulk in a factory in Great Britain. (Pritchard and Wraige, 1953)

	Nov.–Dec.	*May–June*
Moisture, per cent	9·56	10·32
Thiamine	3·9	2·5
Riboflavin	13·5	5·9
Nicotinic acid	46·0	43·7
Pantothenic acid	11·8	5·6
Pyridoxine	11·2	2·7
Vitamin B_{12}	0·1	0·1
Inositol	—	230
Choline	—	4,000

The most instructive information on the B vitamins in fish meals is given in Table VI taken from Pritchard and Wraige (189). It presents amounts of the B vitamins in an average sample of white fish meal produced in bulk in the United Kingdom. It is clearly shown that the amounts can vary considerably, and that possibly a seasonal effect may be responsible for some of the variation.

It is generally recognized that the vitamin B_{12} content of fish meals is of great importance; and since the fish meal supplement is often the only source of this vitamin in a ration, it is important to note that occasionally it may prove inadequate. Recently Wöhlbier, Kirchgessner and Giessler (237) reported that addition of vitamin B_{12} to a ration supplemented with a Peruvian fish meal resulted in improvement in protein utilization. There was no improvement when Norwegian herring meal was used instead of the Peruvian fish meal.

The other important criteria on which the value of fish meal and other fish products for pigs depends (not illustrated by the example given above) are: the moisture content, the oil content, the salt content, palatability, digestibility of main nutrients, biological value of protein and the rather controversial specific growth promoting factor(s), as yet unidentified. H. H. Mitchell wrote in 1943: "available evidence clearly demonstrates that the great effectiveness of animal protein concentrates in promoting maximal production in swine is not due to their protein constituents, but rather to their higher contents of certain vitamins, of calcium, of phosphorus and possibly some micro-nutrients".

The moisture content of fish meal is important for two main reasons: (*a*) it influences the overall nutritive value by determining the amounts of nutrients supplied by a given weight, and (*b*) it determines the storage life of the product. Richardson (193) has experimentally demonstrated, and it is now generally accepted, that the moisture content of fish meal should be below 8–10 per cent, as otherwise deterioration on storage may be substantial (mouldiness, bacterial spoilage, etc.). A high moisture content may also lead to spontaneous heat development, which in extreme conditions may constitute a fire hazard.

The oil content of fish products is of particular importance; it often may be the decisive factor in determining whether a fish product should be used in pig rations. Both the quantity and the quality of the oil has to be taken into consideration. They may affect the palatability of the product, its keeping quality and particularly the quality of the carcass (see later).

The content of salt in fish products can be very high, but its effect on the pig has not been satisfactorily elucidated as yet. Mayerhöfer (164) claimed that fish meal with up to 9 per cent salt may be used in pig rations, and Korrell (128) recorded no harmful effects from feeding fish meal with 11·24 per cent salt. Stang (222) and Honcamp *et al.* (104) compared the value of herring meals with different salt content, and concluded that feeding up to 300 g./pig/day of herring meals containing up to 19 per cent salt had no adverse effect on the pig. The impression was even created that the high salt content may have stimulated appetite of the pigs. It certainly increased their consumption of water. There were no adverse effects on carcass quality. Radeff (192) also found no ill effects with feeding fish meals containing up to 20 per cent salt. On the other hand, one should take into consideration the newer findings of Done, Harding and Lloyd (63), who demonstrated that in some circumstances excess of salt in the ration may have serious adverse effects on the pig.

Acceptability of a product is of importance, as it may influence the intake of food by the pig. Smell and taste play their part, and even a relatively small amount of strongly smelling, stale, or mouldy material may affect a ration adversely. In extreme conditions, the pigs may refuse to eat it; but more often they may consume some of it and digestive upsets may follow.

The chemical composition does not necessarily decide the nutritive value of the product. It is certainly not sufficient to evaluate fish meals solely on the basis of their protein content. Even if one excludes intentional adulterations (and there are several ways in which the protein content of fish meal can be artificially raised), the fact that a fish meal has a high crude protein content does not necessarily signify high quality. The availability and utilization of nutrients often play a decisive rôle. One way of expressing the overall value of a feedingstuff is to state, beside the analytical values, the digestibility of its nutrients, and it is interesting to note that very early investigators of fish meal used this criterion (119, 145, 231). The digestibility of crude protein and of fat in a good quality fish meal is high (90–100 per cent); but it may vary considerably with different consignments, depending to a great extent on the methods of processing.

For example, Honcamp *et al.* (103) determined the digestibility coefficient for a large number of samples of fish meal, and found the range for crude protein 90·8–94·4 per cent and for crude fat 75·3–97·2 per cent. Schneider (209) found that digestibility and biological value of the protein differed considerably when he compared menhaden fish meal ration and vacuum dried white fish meal ration. The latter with 86 and 82 per cent was superior to the former with 74 and 70 per cent. More recently, Drzas and Skulmowski (65) have established digestibility coefficients for pigs of many feedingstuffs, including fish meals.

Another way of expressing the overall value of a feedingstuff with a high protein content is to give the biological value of its protein. In general, the biological value of fish meal is high (70–90), and it is better than in most protein supplements which are commonly used in pig rations (extracted soya bean meal, around 70; extracted groundnut meal, around 60; peas, 60; beans, 50; sunflower meal, 50).

It is interesting that in experiments with pigs Columbus (48) has confirmed Mitchell's finding that biological value of fish meal (like that of other proteins) depends on the level of protein in the ration, as shown in the following figures:

Level of protein in the ration, g./pig/day	*Biological value of fish meal*
50	82·28
100	95·01
150	90·21
200	83·33
250	71·41

One should, however, keep in mind a finding by Hennig (95) that there was no difference in biological value between proteins of animal and vegetable origin, when the test was done on adult sows. This finding awaits confirmation.

About the unidentified factor(s) in fish products one can say very little at present. Most of the claims for its thin existence come from tests on small laboratory animals and chicks. In the past it was often associated with the so-called animal protein factor, and before the discovery in 1948 of vitamin B_{12} there were many pointers that the pigs responded effectively to an unidentified nutritional factor present in fish products. Whether the observed effect can now be wholly explained by the vitamin B_{12} content, or whether the latter offers only partial explanation and other as yet unidentified factors may be involved, is still a controversial issue.

Classification of fish meals

There are so many factors determining the nutritive value of fish products for pigs that it is very difficult to classify them in a way that would allow an easy identification of nutritional properties. In the United Kingdom three groups of fish meal are now clearly distinguished:

White fish meal
Herring meal
Fish meal

In white fish meal one expects a product prepared from white fish (like cod, for example) containing 1 per cent or less oil in the raw material, and simply dried to a meal which must not contain more than 6 per cent oil (usually 2–3 per cent). White fish meal should contain 60–65 crude protein of high biological value. Recently Olley and Watson (173) analysed a large number of samples of British white fish meal, and found them very uniform with "available lysine" value of about 6·2/100 g. of

TABLE VII

Classification and composition of "fish meals", per cent (Breirem, 1953)

	Dry matter	*Crude protein*	*Crude fat*	*Ash*	*Salt*
I. *Herring meal*					
1. Low in salt and fat	91·0	71·3	8·2	8·8	1·6
2. Low in salt	90·5	66·5	11·1	12·4	2·5
3. Slightly salted	90·3	64·7	9·4	14·4	5·1
4. Salt rich	90·0	56·5	12·8	18·5	8·7
Herring press-water	41·6	30·3	2·5	8·3	2·4
II. *Fish meal*					
1. Air-dried fish meal (cod meal), old	85·9	53·9	2·3	27·9	—
2. Air-dried fish meal, new	89·0	49·8	1·4	34·8	—
3. Artificially-dried full fish meal	91·8	73·8	4·1	13·5	—
III. *Liver meal*					
1. Fat rich liver meal	92·6	51·1	29·0	4·3	—
2. Low fat liver meal	90·0	70·4	9·7	6·1	—
3. Low fat, salt rich liver meal	89·0	57·8	2·0	23·8	17·0
IV. *Whale meal*					
1. Fat rich whale meal, old	92·5	76·2	11·7	4·3	—
2. Low fat whale meal	91·9	85·9	4·6	2·6	—
3. Low fat whale meal (Nygaard)	91·1	86·2	2·0	3·2	—
4. Whale feeding meal	91·0	61·8	9·6	14·6	—

protein and digestibility of 96 per cent. Samples of Peruvian white fish meals analysed at the same time were very variable with "available lysine" values ranging from 5·3 to 8·3/100 g. and digestibility above 89 per cent.

Herring meal results from processing herrings with inherent high oil content, which by different methods is reduced to amounts that can be tolerated. The oil content of herring meal may vary considerably. In good-quality meal, it should not exceed 8–10 per cent. The crude protein content is usually a little higher than in white fish meal (65–75 per cent), and the protein has high digestibility and biological value.

The "undefined" fish meal can be anything, ranging from a most satisfactory product to one with very little value as a feedingstuff, and intended to be used as a fertilizer.

In different countries different classifications are adopted. Perhaps the most comprehensive is that in Norway, details of which were given by Breirem (29) which are reproduced in Table VII. Norway is obviously leading the field in the attempts to define their fish products which are intended to be used as feedingstuffs.

It is, of course, very difficult to decide which of the differences in the composition of the meal are material to the pig. Honcamp (101) and Wowra (247), for example, compared a cod meal containing 51·6 per cent crude protein and 30 per cent ash with a cod meal containing 63·6 per cent crude protein and 22·7 per cent ash, and found no difference in the performance of the pig. Similarly, Fevrier, Jacquot, Matet and Pero (77) tested three fish meals, "ordinary" fish meal, "full" fish meal and fish meal hydrolysate. These were prepared by widely different methods of processing (all had similar crude protein content of 51–55 per cent), but the performance of the pigs to which these meals were fed was very similar on all three rations.

Amount of fish meal to be used in pig rations

The quantity of fish meal to be added to a ration of pigs depends on the following four major factors:

(1) The intended quality of the ration (often depending on the class of pigs to which the ration is fed and on the level of performance expected from them).
(2) The composition of the fish meal.
(3) The composition of the rest of the ration.
(4) The cost of the protein supplements.

The above major factors are in turn influenced by many others which cannot be discussed here.

The relatively high cost of fish meal and the frequent scarcity of supplies make it imperative that the amounts used in rations of growing pigs should be carefully measured with the aim of providing just enough to ensure the best possible rate of growth and efficiency of food conversion compatible with a specified quality of carcass. Above a certain level of supplementation these aims may be antagonistic to each other. An increase, for example, may result in an improvement in growth rate and efficiency of food utilization; but it may also cause deterioration in quality of the carcass and meat. On the other hand, an increase in amount of fish meal in the ration need not have any favourable results, and such an increase should obviously be avoided for economic reasons.

The survey of literature which follows and the subsequent remarks are intended as a guide only, as generalizations on this subject should obviously be avoided.

Bünger *et al.* (34) compared rations with two levels of herring meal (125 and 250 g./pig/day) and with a vegetable protein supplement, and concluded that the best performance was obtained on the higher level of herring meal. Carcass and meat quality was not affected; but liver sausage produced from livers of pigs receiving the herring meal had a fishy flavour, particularly with pigs that received the herring meal right up to slaughter time.

Bünger, Hare and Schmidt (38) compared three levels of fish meal supplementation (169, 216 and 250 g./pig/day of digestible protein) in rations composed mainly of cooked potatoes or other bulky foods, and concluded that, though the highest level gave slightly better results than the medium level, the latter was sufficient to obtain reasonable performance. The higher level was considered uneconomical.

Pavlenko (180) found that rations with 10–15 per cent fish meal gave the best results with growing pigs. Woodman and Evans (241–244) have clearly demonstrated that a considerable saving in high-protein supplements is possible by adopting lower protein standards than those recommended previously. Their metabolic studies and feeding tests showed that young pigs receiving a ration with 7 per cent fish meal were able to build up body protein at about equal rate as pigs receiving a ration with 10 per cent fish meal. Thus, on the lower protein ration there was a more efficient conversion of food protein into body protein. Subsequently Evans (72) concluded that, when 7 per cent of white fish meal is added as a supplement to a cereal mixture consisting of 2 parts barley meal and 1 part fine wheat offal (with a small amount of lucerne meal added), with the fish meal contributing 4·4–4·9 per cent of crude protein (total crude protein in the ration, 15·1–16·1 per cent), it supplemented completely the protein of vegetable origin and enabled maximum retention of nitrogen and maximum growth to take place without wastage of amino acids.

Columbus (48) found that the biological value of protein was highest when fish meal was fed at the level of 100 g./pig/day. It was adversely affected by either increase or decrease in the level of fish meal fed.

Commenting on the Deutsche Landwirtschaftliche Gesellschaft Standards, which recommend 3½ per cent fish meal as a protein supplement, Kirsch and Drews (123) suggested that their own experiments showed that by increasing the level to 7 or 8 per cent the performance of the pigs could be improved.

Robinson, Coey and Burnett (200) found no difference in performance of pigs fed up to 150 lb. liveweight rations supplemented with either 7 or 12 per cent fish meal.

Pieterse and Verbeek (183) fed pigs up to 100 lb. liveweight on a basic ration of 65 per cent maize, 25 per cent wheat bran and 10 per cent lucerne meal, supplemented with 0, 2·5, 5·0, 7·5, 10·0 and 12·5 per cent fish meal, and showed progressive improvement in rate of gain and efficiency of food utilization with increasing levels of fish meal. On a ration containing 5 per cent or less fish meal, the surface area and the depth of the eye muscle were significantly reduced, but length appeared not to be affected. Back fat thickness was to some extent inversely related to the level of dietary protein.

Braude, Mitchell, Cray, Franke and Sedgwick (27) fed basic meal containing 5, 7 or 10 per cent white fish meal in conjunction with whey *ad lib.*, and found no statistically significant differences in performance of the pigs or in carcass quality. As there was a slight tendency for deterioration in performance with a reduction in protein level of the ration, the 7 per cent level would be the obvious one to adopt in practice.

Barber, Braude and Mitchell (16) recorded considerably better growth rate and efficiency of food conversion on rations supplemented with 7 per cent fish meal than on rations with 3½ per cent fish meal.

Duckworth, Hepburn and Woodham (67) recorded a graduated response in growth rate, and food conversion corresponding to increases in levels of fish meal in the ration of 3, 5·5 and 8 per cent (giving respectively 13·5, 14·8 and 16·1 per cent crude protein in the ration).

Laksesvela (144) studied the relationship between the level of feeding of herring meal and the performance of pigs and their carcass quality. The herring meal contained 7 per cent oil, and was fed at 3, 4, 5, 6, 8, 10 and 12 per cent of the ration throughout the growing period, or with successive reductions as the experimental period progressed. The rations were compared at each level of protein with rations containing the same amount of protein and energy, but the protein supplement of which was of vegetable origin only. Most improvement in growth rate and efficiency of food conversion was obtained at levels of 6–8 per cent. There was further progressive improvement with the higher levels, but the increments of improvement became smaller above 8 per cent of the supplement. From the point of view of carcass quality there was no adverse effect on rations up to 6–8 per cent of the supplement; but above that level there was a reduction in quality (measured mainly by softness of the fat and reduction of palatability of the bacon). At all levels of supplementation the herring meal was withdrawn when the pigs reached 80 kg. (they were slaughtered at 90 kg.).

As mentioned earlier, when considering the amount of fish meal which one should add in order to produce a well-balanced ration for pigs, one must first of all decide what level of crude protein one wishes to obtain in the final mixture. Next, one should ascertain the crude protein of the cereal mixture and of the fish meal one wishes to use. Table VIII was prepared in order to illustrate the relationship between these three factors. Although only two sorts of fish meal, with 60 and 65 per cent of crude protein, were taken into consideration, the amounts of the fish meal to be used may vary by nearly two and a half times, depending on the crude protein content of the ration and on the crude protein content of the cereals. Figures in Table IX show clearly the possible extensive variations in crude protein content of individual cereals and cereal mixtures often used in pig rations.

The amount of fish meal that will be consumed by pigs of different classes depends mainly, of course, on the amount of food eaten by the pigs and on the percentage of fish meal in the ration. Tables X, XI and XII give calculated amounts for suckling litters consuming creep feed, for sows, and for growing pigs, covering the period from weaning to slaughter at 200 lb. liveweight. For the last group the efficiency of food utilization was taken as

TABLE VIII

Amount of fish meal (60 or 65 per cent crude protein), per cent, of a ration[1] to be added to cereal mixtures with varying crude protein content to achieve rations with required crude protein content

	Crude protein content of a ration, %									
	12		13		14		16		18	
	Crude protein content of fish meal									
Crude protein content of cereals	60%	65%	60%	65%	60%	65%	60%	65%	60%	65%
7	9·5	9·0	11·5	10·5	13·0	12·5	17·0	16·0	21·0	19·0
8	8·0	7·5	10·0	9·0	11·5	11·0	15·0	14·5	19·5	18·0
9	6·5	6·0	8·0	7·0	10·0	9·5	13·5	13·0	17·5	16·0
10	4·5	4·0	6·0	5·5	8·0	7·5	12·0	11·0	15·5	15·0
11	2·5	2·0	4·0	3·5	6·0	5·5	10·0	9·5	14·0	13·0
12	—	—	2·0	2·0	4·0	3·5	9·0	8·5	12·5	11·5
13			—	—	2·5	2·0	7·0	6·5	10·5	10·0
14					—	—	5·0	4·5	9·0	8·5

[1] Rounded off to nearest 0·5%.

TABLE IX

Crude protein content of cereal mixtures when consignments with levels of crude protein stated (extremes) are mixed in proportion of 1 to 1

	Crude protein %	*Barley meal* *a*	*Barley meal* *b*	*Maize meal* *a*	*Maize meal* *b*	*Wheat* *a*	*Wheat* *b*
Barley meal, minimum (*a*) . . .	7·0	7·0	10·5	6·5	8·5	9·5	12·5
maximum (*b*). . .	14·0	10·5	14·0	10·0	12·0	13·0	16·0
Maize meal, minimum (*a*) . . .	6·0	6·5	10·0	6·0	8·0	9·0	12·0
maximum (*b*) . . .	10·0	8·8	12·0	8·0	10·0	11·0	14·0
Ground wheat, minimum (*a*) . .	12·0	9·5	13·0	9·0	11·0	12·0	15·0
maximum (*b*) . .	18·0	12·5	16·0	12·0	14·0	15·0	18·0

TABLE X

Amount of fishmeal, in lb., consumed by a suckling litter eating a certain amount of creep feed containing different levels of fishmeal

Amount of creep feed eaten by the litter	*Amount of fishmeal in creep feed, %*			
lb.	5	10	15	20
50	2·5	5·0	7·5	10·0
100	5·0	10·0	15·0	20·0
150	7·5	15·0	22·5	30·0
200	10·0	20·0	30·0	40·0
250	12·5	25·0	37·5	50·0

TABLE XI

Amount of fish meal, in lb./year, consumed by a sow, producing 2 litters of 10 pigs each, depending on the percentage of fish meal in the ration

Percentage of fish meal in the ration	2	3	5	7	10
lb. of fish meal/sow/year	57	85	142	199	284

TABLE XII

Amount of fish meal, in lb., consumed by a pig from weaning to 200 lb. liveweight depending on the percentage of fish meal in the ration and efficiency of food conversion

Amount of fish meal in the ration	*Efficiency, lb. meal/lb. liveweight gain*				
%	3·0	3·5	4·0	4·5	5·0
2	9·6	11·2	12·8	14·4	16·0
3	14·4	16·8	19·2	21·6	24·0
5	24·0	28·0	32·0	36·0	40·0
7	33·6	39·2	44·8	50·4	56·0
10	48·0	56·0	64·0	72·0	80·0
7 reduced to 3 at 120 lb. liveweight	22·4	26·4	30·4	34·4	38·4
10 reduced to 3 at 120 lb. liveweight	28·4	33·6	38·8	44·0	49·2

the criterion on which the amount of food consumed was calculated. Values in these tables can be used as a rough guide, when calculating the requirements for fish meal in a single piggery, in a district or in the country as a whole.

In the United Kingdom, if white fish meal was used as the sole protein supplement to cereal rations, the amount required to produce one pig weighing 200 lb. would be 41·7 lb. The following assumptions were made in arriving at this figure:

(1) The sow ration contained 7 per cent white fish meal, and the sow produced 16 weaners per annum.
(2) The creep ration contained 15 per cent white fish meal, and the litter of 8 pigs consumed 150 lb. of creep meal.
(3) The growing ration fed up to 120 lb. liveweight contained 7 per cent white fish meal and 3 per cent thereafter, and the pig required 3½ lb. of the ration per lb. liveweight gain.

Fish meal compared with other protein supplements

A very large number of tests have been carried out throughout the world comparing the value of fish and herring meal with that of other feedingstuffs used as protein supplements in pig rations. One of the earliest experiments (and most probably the first test on this subject in the United Kingdom) was that of Crowther (54). Other early pioneers included Orr, Crichton and Green (178), Isaachsen and Ulvesli (116) and Hansson (90).

The early tests aimed at demonstrating that fish meal is a satisfactory protein supplement; and many later tests were directed towards proving its superiority over other supplements. When attempting to interpret the available evidence, one must keep in mind that, as time progressed, considerable improvements were introduced in the processing methods of both fish meal and other protein supplements, so that old evidence may not be applicable to more recent products. The extent to which the composition of fish meal can vary has been referred to earlier; but the variation in the composition of most of the other protein supplements can also be very considerable. Results of a test apply only to the specific consignments of protein supplements used in it. Thus, a large number of comparative tests is necessary before any general conclusions can be drawn on the nutritive value of protein supplements used in individual tests. Another important consideration, often overlooked, when two sources of protein are compared, is that differences in nutritive value can only be effectively demonstrated when excess of protein in the test ration does not obscure them.

Fish and herring meals provide protein of "animal" origin, and when mixed with cereals result in ration of "mixed" protein origin. There are, of course, other protein supplements of animal origin that are used in preparation of mixed protein rations for pigs. On the other hand, many of the protein supplements employed are of vegetable origin; and when these are mixed with cereals, the resulting rations are classified as containing vegetable protein only.

Recently two papers have been published dealing with basic aspects concerning the comparison of animal and vegetable protein supplements in pig feeding. Hill and Prinz (97) claimed that the absence of animal protein in the ration was responsible for a great reduction in the content of certain amino acids in muscles and livers of pigs. In their experiments, rations with 10–15 per cent fish meal were compared with rations containing no animal protein.

The other most interesting report was that by Pres and Nowicki (186) which claimed that, when fish meal was included in the ration of pigs, their stomachs and small intestines were heavier, while their large intestines and caecums lighter than in pigs receiving vegetable protein only. The authors attempted to explain these differences on the basis of a hypothesis suggested by Mangold (157), namely that with fish meal enzymic digestion takes place in the small intestines, but with vegetable protein bacterial digestion starts in the caecum.

Skim milk. Skim milk, either liquid or dried, is generally recognized as an excellent protein supplement for pig rations. Most of the published evidence indicates that fish meal can satisfactorily replace skim milk (2, 57, 79, 94, 118, 138). The Danish results of Jespersen and Hansen (118) are based on an extensive series of comparative tests leading to the general conclusion that, as far as growth rate, efficiency of food utilization and effect on health are concerned, fish meal and skim milk supplements are of about equal value; but the fish meal rations, particularly when fed right up to slaughter time, may adversely affect the colour, texture and taste of the bacon. In some of the experiments, pigs receiving skim milk rations ate more food; but as they did not grow faster, their efficiency of food utilization was slightly inferior to that of pigs receiving the fish meal rations. Danish workers have continued their comparative tests, but an up-to-date account has not been published; from several public statements by Professor Clausen, one can surmise, however, that the earlier results have been substantiated and that the effect of fish meal rations on carcass and bacon quality is still causing anxiety. In practical feeding routine in Denmark it is necessary to discontinue fish meal supplements some time before the pigs are sent to slaughter.

Breirem (29) showed that the nutritive value of herring meal is equal to that of skim milk when used as a supplement to a cereal-potato ration. However, as occasionally the herring meal may adversely affect the meat quality, Breirem suggested that a mixture of the two supplements may be preferred.

In England, Braude *et al.* (25, 26, 27), Barber, Braude and Mitchell (15) and Barber *et al.* (12) compared the value for growing pigs of high quality white fish meal and either liquid or dried skim milk, and found that on equal protein basis the skim milk was slightly superior to white fish meal as a protein supplement. The reason for this alleged superiority has not yet been elucidated. It is of interest, however, that no differences were observed in carcass quality.

Other protein supplements of animal origin. Kernot and Speer (120) found that by using best white fish meal as a supplement they obtained better growth rate and food utilization than with a mixture of blood meal and bone flour. Foster and Hostetler (78) obtained better results with fish meal than with tankage. Woodman and Evans (241) found equal performance on rations supplemented with white fish meal to that obtained on rations with a mixed protein supplement consisting of blood meal, skim milk and soya bean meal. Willman and Morrison (232) obtained excellent results in four tests by substituting tankage with white fish meal; but in two other tests in which menhaden fish meal was compared with tankage, the results favoured tankage. Cook (52) obtained equal results when using either fish meal or meat meal as protein supplements. Robinson (201) summarized results of 15 tests in which fish meal was compared with tankage as a supplement to maize rations. On average the fish meal ration gave 1·52 lb. daily liveweight gain and the pigs needed 3·8 lb. of meal/lb. gain, while the corresponding values for tankage were 1·40 and 4·05 respectively, leading to the conclusion that fish meal is worth 16·7 per cent more than tankage. On the other hand, when a "trio mixture" (tankage, linseed meal and lucerne meal) was used it gave slightly better results than fish meal. Kyzer *et al.* (142) and Ferrin (76) obtained better results with fish meal than with tankage used as a supplement to maize rations.

Jespersen and Hansen (118) found that pigs receiving a ration supplemented with fish meal during the whole growing period (20–90 kg.) grew better and utilized their feed more efficiently than pigs fed on this ration only up to 60 kg. and thereafter a ration supplemented by meat and bone meal.

Wöhlbier, Kirchgessner and Schneider (238) found that pigs did equally well on a balanced ration with a mixture of protein supplements and on cereals to which some fish meal was added daily. Oslage (176) also found no difference in performance of pigs receiving rations supplemented by either fish meal or meat and bone meal.

Soya bean meal. Kronacher (135) reported that replacement of two-thirds of the fish meal supplement by soya bean meal adversely affected the performance of the pigs. Similar results were obtained by Malkomesius (156), Honcamp (104), Wowra (247), Bünger *et al.* (35) and Ferrin (76).

Frens and Ubbels (81) claimed that pigs receiving a ration supplemented with 8 per cent Norwegian herring meal grew and utilized their food better than pigs on a ration supplemented with 5 per cent soya bean meal and 5 per cent sunflower meal.

Evans (72) concluded from extensive tests which included metabolic studies that protein in soya bean is inferior to the protein in white fish meal for supplementing the proteins in a cereal mixture consisting of barley meal and fine wheat offal. Thus, in order to secure equal rates of liveweight increase in young pigs the soya bean ration had to supply about 12·9 per cent digestible protein as compared with 12·3 per cent for the fish meal ration.

Hvidsten and Husby (113) also found that rations with herring meal gave superior performance; that was true even when the soya bean ration was supplemented with fish solubles.

Comberg and Staunde (49) found that a ration with 200 g./pig/day of fish meal gave very much better growth rate and efficiency of food utilization than a ration supplemented with 300 g./pig/day of soya bean meal.

Laksesvela (144) also obtained better performance with herring meal added at several levels than with rations of equal protein content containing soya bean meal as the protein supplement.

On the other hand, Kirsch (122), Kirsch and Fender (124) and Rabold and Schoen (191) found no difference in performance of pigs when fish meal was replaced by steam-heated soya bean meal. Schiller (206) found that the performance on rations containing soya bean meal could not be improved by addition of fish meal.

Becker *et al.* (17) using menhaden fish meal found that for pigs up to 100 lb. liveweight a ration of 16 per cent crude protein gave satisfactory results. However, equal results were obtained on rations with only 14 per cent crude protein when soya bean meal was used as the protein supplement. With pigs above 100 lb. liveweight both supplements were equal in value. With rations low in crude protein the menhaden fish meal was less satisfactory than soya bean meal, but they were equal in rations containing 18 per cent crude protein. Becker and his co-workers suggested that it may be that the tryptophan content was the limiting factor in the maize-menhaden fish meal ration. Some American workers expressed recently their belief that soya bean meal is superior to fish meal as protein supplement for pig rations. Although this is not in line with most of the published evidence, it was as early as 1928 that Davidson (60) claimed that in some tests better results were obtained with extracted soya bean meal than with fish meal.

Groundnut meal. The earlier tests showed little or no difference in performance of pigs receiving rations supplemented either by fish meal or groundnut meal (55, 60, 179, 219). However, already Kronacher (135) had found that replacement of two-thirds of the fish meal supplement by groundnut meal adversely affected the performance of pigs fed these rations. Also Malkomesius (156) obtained better results with herring meal than with groundnut meal, and so did Foster and Hostetler (78) and Van der Vyver (225). Certainly the more recent tests point to the superiority of fish meal over groundnut meal for rations for growing pigs. This was clearly demonstrated by Woodman and Evans (245), whose results were confirmed by Robinson, Coey and Burnett (200), Carpenter *et al.* (42) and Smith and Lucas (212).

Other protein supplements of vegetable origin. There is overwhelming evidence indicating that fish meal as protein supplement to rations of growing pigs considerably improve their growth rate and efficiency of food conversion in comparison with rations containing protein of vegetable origin only. A selection of references indicates clearly that the conclusion applies generally, independently of the source of the vegetable protein used; linseed meal (163), field peas (138, 194); barley meal + whey (234), bean meal (60), sunflower meal (204, 219); cotton seed meal (78); sweet lupins (39, 50, 229); mixed vegetable proteins (14, 158, 224); several different sources (113).

There are, however, a few exceptions. Kitchin (127) found lentil meal as satisfactory as fish meal as a protein supplement to rations of growing pigs; and more recently Barber, Braude and Mitchell (16) and Duckworth, Hepburn and Woodham (67) found no difference in the performance of pigs, when dried leaf meal was compared with white fish meal as protein supplements to rations of growing pigs.

Schiller also (206) obtained no significant improvement by adding fish meal to a ration supplemented with sweet lupins. She has established, however, that the biological value for the lupins was 57, and for a mixture of 80 per cent lupins and 20 per cent fish meal 68.

Dried yeast. Malkomesius (156), Bünger (32), Bünger, Fissmer and Hare (36), Richter and Brüggemann (196) and Crasemann and Tscherniak (53) obtained very similar results indicating that fish meal supplemented rations are superior to those supplemented with dried yeast. They all found that half fish meal half dried yeast supplement gives equal results to fish meal alone.

Evans (72) found, however, that in metabolic and feeding trials, when a basic ration of barley meal and fine wheat bran is used, both white fish meal and dried brewer's yeast (providing one-third of the total crude protein of the ration) will allow maximum retention of nitrogen and maximum growth to take place without wastage of amino acids.

Protein supplements of mixed animal and vegetable origin. Evidence is accumulating that a considerable saving in animal protein may be obtained by feeding a mixture of animal and vegetable protein supplements. For example, a small amount of fish meal may effectively complement the proteins of vegetable origin, and a mixed supplement included in rations for pigs may result in equal performance to that obtained on rations with animal protein as the sole supplement (50, 206, 224, 242, 245; see also preceding section on dried yeast).

Fish oil

Fish oils are of importance in pig feeding from three aspects: (*a*) as a source of fat soluble vitamins, (*b*) as a source of energy, (*c*) as ancillary ingredient of the high protein supplements prepared from fish.

The amount of oil contained in fresh fish may vary considerably; but for the purpose of this review it is sufficient to make a distinction between lean fish (e.g. cod) and fat fish (e.g. herring) and to mention that the oil content of herrings may vary considerably with the season of the year (low in the spring—average about 4 per cent, and high in the late autumn—average about 17·5 per cent). The chemical composition of fish oils also varies; but here again one has to limit the description of the fatty acid content of fish oils to stating that they contain a high proportion of unsaturated fatty acids. These oils are highly affected by oxidation, and decompose fairly rapidly. When fish meal or other fish products with such decomposed oil are mixed into pig rations they cause a strong oily or fishy flavour in the meat. Incidentally, for detecting these defects in bacon, Askoe and Madsen (8) described a colour test in which they used thiobarbituric acid as a reagent. However, Haskell *et al.* (91) claimed that the thiobarbituric acid test was not specific for detecting the fishy flavours in meat.

A comprehensive review of papers on fish oils published before 1933 was written by Schmalfuss, Barthmeyer and Werner (207). Manning (159) published a bibliography on cod liver oil in animal feeding with non-critical comments and abstracts. A most useful source of information on all subjects concerning marine oils is the Canadian bulletin edited by Bailey, Carter and Swain (9). Banks and Hilditch (10) discussed and compared the chemical composition of fish oil and pig fat, and suggested that the fishy flavour occasionally occurring in pig meat may be due to the high amount of the unsaturated, C_{20}–C_{22}, fatty acids in pig fat. The softness of pork fat often associated with the feeding of fish products may be due to the large amounts of linoleic acid present in such fats. The results of Husby (109), who studied in detail the fatty acids contents in two pigs, one of which was fed 90 and the other 204 g. of herring oil per day, tended to confirm these explanations. The amount of free fatty acids in fish meal may vary from 5 to 30 per cent. Often in the past the level of free fatty acid was taken as an indicator of quality, but recent results tend to disprove its usefulness (23, 143).

When considering fish oils as a source of fat soluble vitamins for pigs, one must underline that it is fish liver oils which are usually concerned. Fish oils have normally a rather low vitamin A and D content when compared with fish liver oils, as shown clearly in the following values taken from Bailey, Carter and Swain (9):

	Vitamin A i.u./g.	*Vitamin D i.u./g.*
Tuna liver oil	50,000–1,000,000	16,000–30,000
Halibut liver oil	4,000–165,000	550–20,000
Cod liver oil	550–30,000	85–500
Herring oil	30–300	25–160
Menhaden oil	340–500	50–100
Pilchard oil	100–500	20–100

With the advent of synthetic vitamins the use of fish liver oils in pig rations is on the decline. A comparison of efficiency for pigs of these two sources of vitamins A and D has been made by Barber *et al.* (11).

The current revival of interest in fish oils is connected with the prospect of high energy rations for pigs. The use of fish oils for this purpose has become a possibility since the new methods of processing may remove the main objection to their use, viz. the tendency to impart fishy taste and smell in meat of the pigs to which these oils are fed. For example, Jahn (117) claimed that the new low temperature process developed in East Germany resulted in a product which is very palatable to the pigs, and which, when consumed in relatively high amounts, does not lead to digestive upsets or adversely affect the quality of the meat.

Most of the experimental work on pigs was directed towards the study of the effects of different levels of fish oil in the ration on the composition of the pig fat and its taste and smell. An extreme example is that reported by Garton, Hilditch and Meara (84), who fed a single pig on a ration containing 50 per cent crude whale oil (up to 4 lb. oil/day). At slaughter at 200 lb. (reached in 198 days), the pig was apparently in good health. The depot fat had a yellowish-brown discoloration. A considerable proportion of the characteristic whale oil fatty acid had passed nearly unchanged to the fat depots of the pig. On the other hand, Garton and Naftalin (85) who fed cod liver oil in amounts up to 25 per cent of the ration, found that pigs ate the food and appeared normal for about 6 weeks. After that period, digestive upsets started and, when the pigs were killed on the forty-ninth day, there was "exudative diathesis"—massive oedema. It is of interest that the pigs' livers appeared normal.

In the early 'twenties Orr and Crichton (177) used smaller amounts of fish oils, namely, 9 ml./kg. ration of either cod liver oil or herring oil, and compared the effect with that of similar amounts of olive oil and of no supplementary oil. The performance of the pigs was not affected, but the fish oils were responsible for a "marked offensive fish taste that made the bacon quite uneatable."

Brown (31) added 14 per cent of menhaden fish oil to a maize-tankage ration, and found that it caused a marked yellow discoloration of the carcass. Although in the fresh carcass the fishy flavour was scarcely noticeable, on cooking it penetrated all parts of the carcass. Even the innermost parts of the tongues were highly flavoured. It is of interest that Brown found that the highly unsaturated fatty acids deposited in the carcass fat were of about the same molecular weight and liver iodine value as the mixture of fatty acid in the menhaden fish oil.

Frazer, Stothart and Gutteridge (79) compared the value of cod liver oil with that of pilchard oil fed at the rate of 0, ½, 1 and 2 oz./pig/day. At all levels of supplementation there was an improvement in growth rate and efficiency of food conversion, and there was no difference between the two oils. However, to prevent a fishy flavour in the pork the feeding of the oils had to be stopped 30 days before the pigs were slaughtered.

Husby and Haug (110) recommended that pigs fed for production of fresh meat receive not more than 25 g. of fish oil per day, and bacon pigs not more than 10 g., as oxidation during storage accentuates defects in flavour. Administration of fish oil should be discontinued 6 weeks before killing.

Vestal *et al.* (227) added 0·5 or 1·5 per cent of fish oil to a ration containing 10 per cent fish meal (with 5 per cent oil) and found that it caused marked fishy flavour in pork, while the same ration without the oil supplement gave completely satisfactory carcasses.

Gorham, Boe and Baker (88) studied the so-called "yellow fat disease" which has been noted in some pigs fed excessively on fish or fish products. Such pigs often had yellowish or greyish-yellow adipose tissue. The authors claimed that two factors were mainly involved; excessive amounts of highly unsaturated glycerides and inadequate amounts of tocopherols—resulting in acid-fast pigment accumulating in the adipose tissue (mechanism not understood). The condition was reproduced experimentally by feeding a ration 85 per cent of which consisted of frozen fish scraps.

Robinson and Coey (198) supplemented a normal ration containing 5 per cent fish meal with 5 per cent cod liver oil. They recorded normal performance of pigs fed on this ration, but after slaughter the back fat was deep yellow-brown in colour and had a slightly "oxidized odour". The carcasses were condemned as unfit for curing. The peroxide value of samples of extracted loin fat was 5, the iodine value 74 and vitamin E content 0. Samples of fat from pigs receiving the same treatment but also daily 50 mg. *dl* α-tocopheryl acetate were normal with peroxide value of 0, iodine value of 80 and 2·8 mg./100 g. of vitamin E.

Davis and Gorham (61) described the pathology of natural and experimental cases of "yellow fat disease".

The problem of cod liver oil toxicity to pigs has arisen from time to time. Scorgie and Miller (210, 211) surveyed the evidence on the subject and also carried out their own investigations; they concluded that, provided the cod liver oil is genuine and of good quality, the feeding of it, even at very high levels (up to 8·3 per cent of the ration), does not produce liver dystrophy, as claimed by several authors (22, 92, 170, 185, 223, 228, 230). Worden (246) may have produced an explanation for the different findings concerning liver dystrophy, by establishing that feeding of 1, 2 and 5 per cent of cod liver oil containing an antioxidant produced no liver dystrophy and, incidentally, no discoloration of fat or fishy taint. Possibly the preservation of the oil with the modern antioxidant was the material factor. Increasing the levels of cod liver oil resulted in improvement in efficiency of food utilization and in an increase in the iodine value of the body fat which, however, was not accompanied by any visual softening of the fat.

On the other hand Dodd and Newling (64) reported recently an outbreak of acute dietetic hepatosis with severe degenerative lesions of skeletal and cardiac muscle, and believed that it was caused by the fish liver oil emulsion which was used in the rations as a source of vitamins A and D.

Anglemier and Oldfield (6) have tried to establish the value of sardine oil as an energy source for pig rations. They found that addition of 2·75 and 5 per cent of such oil produced good performance and no adverse effects, as compared with a control ration with no added oil. At 8·25 per cent level the animals failed to eat the amount given, and after 4 weeks on test their gain in weight was less satisfactory than that of control pigs. Although total quantitative fat deposition was not markedly different, the quality of the depot fat in terms of colour, odour and hardness was lowered when oil was fed (most marked at the 5·5 and 8·25 per cent level). These fat characteristics made the meat cuts from pigs thus fed unpalatable, and unacceptable from a market standpoint. Feeding of non-fish oil for many weeks before slaughter subsequent to the sardine oil, did not improve matters (except for hardness of the fat).

Oldfield and Anglemier (172) and Anglemier (5) also fed crude pilchard oil to pigs and found that already at 2·75 per cent and certainly at higher levels, a marked decrease in the quality of carcass fat resulted, which could not be remedied by withdrawing the oil even as long as 13 weeks before slaughter. They also found that crude and alkali washed, bleached menhaden oils, when fed at dietary level of 5 per cent, caused undesirable fishy odour and imparted a slight brownish tinge to the carcass. On the other hand, carcasses from pigs fed 5 per cent polymerized menhaden oil were practically indistinguishable from the controls, though occasionally objectional cooking odour was noted. The authors suggested that in view of these facts it may be possible to modify the polymerization process in order to improve the nutritional qualities of fish oils.

Many workers compared the value of fish meals with different oil contents; a few representative opinions are quoted below:

Orr and Crichton (177) compared fish meals with either 3 or 20 per cent oil, and found no difference in performance, but the 20 per cent fish meal ration gave bad fishy taste to the bacon.

Honcamp *et al.* (104) fed herring meal, up to 300 g./pig/day, of 1·9 and 21·7 per cent oil content, and concluded that the ration with the high oil content, more often than not, improved the growth rate of pigs, and had no adverse effect on carcass quality, or on the taste and smell of the meat (except for liver and brain which had fishy taste). Similar results were obtained by Bünger *et al.* (34) who fed low- and high-oil herring meals at 250 g./pig/day.

Jespersen and Hansen (118) compared specimens of fish meal with about 1 and 9 per cent oil content, and found that pigs receiving the higher level grew faster and utilized their food more efficiently, though the taste, texture and colour of the bacon were often adversely affected.

Breirem (30) also obtained excellent performance when feeding herring meal rich in oil, but recommended that in order to avoid defects in carcass quality (soft and yellow fat) the level of supplementation with herring meal should not exceed 7–8 per cent of the ration.

On the other hand, Hellberg, Dahl and Appelgren (94) who compared fish meal with 5·2 per cent oil and herring meal with 12 per cent oil, both fed at 7·4 per cent of the ration, found no difference in performance of the pigs. In spite of the fact that the fish and herring meals were omitted from the rations several weeks before slaughter, the quality of the meat was adversely affected in both groups, but to a greater extent on the high oil ration.

Clausen *et al.* (45) made extensive tests, aimed at establishing effects on carcass quality. They fed rations supplemented with herring meals of 0·3–0·6 per cent or 7·9 oil content. They did not obtain results that would allow definite conclusions to be drawn, but provided some pointers indicating in what circumstances adverse effects on meat quality may occur.

Pinkulis (184) concluded that up to 200 g./pig/day of fish meal can be safely fed without adversely affecting the quality of the meat, provided the amount of fish oil does not exceed 20–25 g./pig/day.

Laksesvela (143) compared rations containing herring meal with both low and high fatty acid content, and recorded a tendency for better growth rate and efficiency of food utilization on rations high in fatty acids. High amounts of free fatty acid did not adversely affect the health of the animals, nor the taste of their body fat.

Carcass quality

In present-day pig production both carcass and meat quality are of the utmost importance. The food consumed by the pigs will to a great extent determine these qualities, and fish products have often been responsible for adversely affecting them.

In 1923 Orr and Crichton (177) wrote: "fish meal is such a valuable food for pigs that it would be a loss to the farming community if the use had to be stopped on account of the liability to spoil the bacon. It seems desirable that fish meal manufacturers should make certain that the fish meal sold to be fed to pigs is made only from non-oily white fish residues. Oily fish meal need not be discarded as a feedingstuff; it can be used for boars and brood sows."

In the papers screened for this review 54 dealt with effects on carcass and meat quality. Of these, 37 reported no adverse effects, but 17 recorded more or less severe faults due to the presence of a fish product in the ration. Most of the fishy taste and smell was associated with the amount and quality of the fish oil in the ration. Often the remedy advocated against "fishiness" was the withdrawal of the fish product from the ration of the pigs at least 3 weeks before slaughter.

In recent years great advances were made in the field of processing and preservation of fish, and excellent quality products can nowadays be prepared from fish rich in oil. Modern methods, and particularly the use of antioxidants (provided the raw material is of reasonable quality), can ensure that any fish product used as a feedingstuff for pigs has no adverse effects on carcass and meat quality. However, even as recently as 1957 Dahl concluded that fat from pigs fed on fish meal has a fishy or oily flavour, is soft and has inferior stability as evidenced by organoleptic, thiobarbituric and accelerated rancidity tests as well as by iodine number. It is thus obvious that the quality of some of the products used at present is a long way from what it should be, and great vigilance is called for to ensure that "fishy products" do not spoil the well deserved good name of the reputable products.

Fresh fish

Very little information is available on feeding fresh fish to pigs. Bünger (1939) and Bünger *et al.* (1939) fed growing pigs on $\frac{1}{2}$ or $\frac{4}{5}$ kg./pig/day of washed salted herrings containing 18·6 per cent dry matter, 7 per cent crude protein, 6·7 per cent oil and 3·1 per cent ash and compared the results with those obtained on a ration supplemented with fish meal. In general, the pigs did not like the salted herrings, but consumed the ration with $\frac{1}{2}$ kg. herrings and grew normally on it, while consumption on the four-fifths herring ration was reduced, and accordingly the growth was impaired. The water consumption of the pigs receiving the herring rations was considerably increased. With the lower quantity of herrings the carcass showed slight yellow discoloration, but this could be almost wholly avoided by leaving out the herring supplement from the ration during the last 4 weeks before slaughter. On the higher herring ration the colour and carcass quality, both in fresh meat and after smoking, was adversely affected independently of whether it was fed right through or was withdrawn 4 weeks before slaughter. The results suggested that fresh herrings should preferably be fed to supply only a part of the protein supplement required for pigs intended for slaughter.

Pecht (181) fed 1 kg./pig/day to growing pigs of ground frozen fish, containing 16·2 per cent crude protein and 3·1 per cent fat, with satisfactory results.

Fish solubles

The liquor pressed out during the manufacture of fish meal is called stickwater. It usually contains 6–10 per cent dry matter consisting of the water soluble material derived from the fish, the nature of which will vary according to the species of fish used in the manufacture of the meal, and the method of processing the meal, and subsequently the methods of handling the liquid. The liquid is concentrated to a varying dry matter content (normally 40–50 per cent), and marketed as fish extract or fish solubles. On a dry matter basis, fish solubles may contain up to 35 per cent of crude protein. A large proportion of the nitrogen, however, usually more than half, is in the non-protein form and only less than half is present in the form of amino acids. The percentages of oil and ash in fish solubles are usually low.

Fish solubles are not normally used as a major source of nutrients for pigs, though they are sometimes used on account of their relatively high content of some of the B vitamins, and even more as a source of the controversial unidentified factor(s). The values given below, taken from Breirem (29, 30) are instructive about the content of B vitamins in fish solubles.

	Dry matter %	*Riboflavin* *mg./kg.*	*Nicotinic acid* *mg./kg.*	*Pantothenic acid* *mg./kg.*	*Vitamin* B_{12} *mg./kg.*
Vacuum condensed herring soluble	50	14	175	100	0·8
Ordinary herring meal	90	5	68	17	0·23

A product akin to fish solubles is sometimes offered under the name "liquid fish" (43, 86, 197). It is a processed mixture of presscake and press-water, obtained after whole fish and fish trimmings are processed and cooked to remove the oil.

The survey of literature on the value of fish solubles as a supplement in pig rations does not lead to any definite conclusions. The evidence is often contradictory, but one gets the impression that the results of more recently conducted tests tend to discount the value of the product for pigs. However, there are some exceptions.

Most probably the first published report on the use of fish extract in pigs' rations is that of Stahl and Friedrich (218) who obtained good response, when replacing with fish solubles a fish meal-soya bean meal supplement in a ration of cereals and potatoes. Lenkeit *et al.* (147) analysed several samples of fish solubles and, on the basis of chemical analysis, followed by some digestibility trials, recommend that fish solubles should not be wasted in Germany, but fed as a supplementary food for livestock.

Several reports followed confirming the beneficial effect of small additions of fish solubles to a variety of pig rations containing vegetable protein only (3, 43, 47, 86, 108, 134, 149, 202, 248). Stahl, Ritze and Wiesner (221) used dried fish solubles mixed with bran in proportion 1 : 1. The dried fish solubles were tested against three other animal protein factor supplements or against a supplement of 1 kg./pig/day of skim milk, and produced the best growth rates.

On the other hand, Becker (18), Van der Vyver (226), Robinson, Coey and Burnett (199), Evans (73), Rutledge (203), Conrad, Plumlee and Beeson (51) recorded no improvement from addition of fish solubles to rations containing vegetable protein only, and the results of Frens and Ubbels (81) and Dyer *et al.* (68) were not conclusive.

The evidence is much more definite that there is no advantage in adding fish solubles to rations with adequate fish meal content (81, 113, 131, 138, 224).

In recent years, with the improvement in processing methods, the idea was developed in Norway (30) to return the fish solubles to the fish or herring meals and produce so-called "complete meals", Sperling (216) tested a "complete" fish meal and a "complete" herring meal as supplements to pig rations, and found them superior to "ordinary" meals. On the other hand, Fevrier *et al.* (77) and Dammers (57) found no difference in the performance of pigs receiving either "complete" or "ordinary" herring meals.

Some workers used fish solubles in larger amounts. Evans (73) tested fish solubles as a source of protein to supply a similar amount to that provided by 7 per cent of white fish meal, and found it distinctly inferior (confirmed by nitrogen balance determinations). The fish solubles had, however, some supplementary value with cereal proteins. Throughout these tests, when fish solubles were used as the sole protein supplement it was noticed that the ration was rather unpalatable to the pigs.

Krüger and Hinrichsen (138) claimed that half of the 80 g./pig/day allowance of fish meal could be replaced by fish solubles without adversely affecting the performance of the pigs.

Kraack (130) claimed that supplementation of a cereal-potato ration with 250 g./pig/day of fish solubles results in better performance than when 150 g./pig/day of soya bean meal was used. In a later test, Kraack (132) found that the performance of pigs on cereal-potato ration supplemented with 250 g./pig/day of fish solubles could not be improved by additions of either 50 or 100 g./pig/day of fish meal. The author goes so far as to suggest that, when enough of vitamin B_{12} is provided by the fish solubles, the addition of fish meal has no beneficial effect. Comberg and Staunde (49) found that a ration supplemented with 200 g. of soya bean meal + 100 g. fish solubles per pig per day gave better growth rate and efficiency of feed utilization than a ration supplemented with 300 g./pig/day of soya bean meal, but that the improvement did not equal the performance obtained on a ration supplemented with 200 g./pig/day of fish meal. A supplement of 150 fish meal + 50 fish solubles gave nearly as good results as the 200 g. supplement of fish meal alone.

Fish silage

Large quantities of fish and fish offals are wasted each year in coastal areas not serviced by fish meal factories. Inland, the fish waste is usually of poor quality and not sufficient for economic production of fish meal. In order to utilize these waste products, a lot of research and development work has been directed in recent years to the production of undried products for feeding to livestock. The preparation of fish silage offered good prospects. Usually addition of a preservative is involved. The type and condition of the raw material determines to a great extent the quality of the silage. Fresh silage is of high quality only if made from lean fish. With high-fat (e.g. herrings), cooking must precede the ensiling process, in order to remove the fat. From the commercial point of view the cooked silage has an advantage, as it provides two soluble by-products: fish oil and fish solubles.

Dried silage can be prepared from cooked silage. Mixed silages have also been tried; on one hand slaughterhouse waste, antibiotic mycelia, etc., have been added, to enhance the value of silage as a supplement; on the other bulky foods like potatoes have been ensiled together with fish in order to produce a nutritionally balanced feed for pigs.

The nutritional value of fish silage as a protein supplement for pigs has been established, but it is generally accepted that the feeding of fish silage (particularly if continued right up to slaughter) may result in off-flavours in the meat.

Olsson (174) was most probably the first to describe ensiling processes for fish and fish waste. Methods described were those using AIV acid + molasses, formic acid, or lime as preservatives. Methods of making fish silage and its value in livestock feeding were also described by Jahn (117), Lund (153, 154), Petersen (182), Presthegge (187) and Sperling (213, 215).

Kirsch, Jantson and Sieden (125), Kirsch and Plaude (126), and Kirsch (122) recommended the production of mixed potato-fish silage, claiming that raw or cooked fish, and either cooked or ensiled potatoes will give good results. 100 kg. potato silage + 7½ kg. fresh fish produced silage of excellent quality. These authors also obtained good fish silage using formic acid as a preservative.

Dammers and Dijkstra (59) produced fish silage by two methods: using 5 per cent AIV acid or 2 per cent AIV acid + 20 per cent molasses. Both silages, which had to be carefully neutralized before feeding, fed at the rate of 1 kg./pig/day to young growing pigs receiving 1 kg. cereals + potatoes *ad lib.* were found satisfactory. However, to prevent a fishy taste in the meat, the feeding of the silages had to be limited to the first part of the growing period.

Pecht (181) found that fish silage made from fat fish (particularly herrings), when fed as a supplement to potatoes, resulted in good performance of the pigs, but that the meat and fat were tainted, even when the silage was withdrawn from the ration 4–6 weeks before slaughter. Fish silage from lean fish produced no adverse effects. No differences were recorded when the value of fish silage was compared with that of fish meal as a protein supplement to cereal rations.

On the other hand, Olsson and Olofsson (175) found that a ration supplemented with fish meal gave better growth rate and efficiency of food utilization than rations supplemented with fish silage.

Freeman and Hoogland (80) recommend the use of concentrated sulphuric acid for preparation of fish silage which has to be neutralized by ground limestone or chalk before use. Pigs receiving half of their ration as neutralized fish silage with no other ingredient of animal origin grew well; but the authors suggested that possibly 25–35 per cent of the ration may be preferred. They advised that the feeding of the silage should be discontinued 2–3 weeks before slaughter to avoid fishy taste in meat.

Jahn (117) described an experiment by Comberg and his co-workers, in which a comparison was made of raw or cooked fish silage with fish meal, all produced in "inland areas". The raw fish silage was a little higher in crude protein content, as some fish solubles were separated during cooking. On a protein basis 200 g./pig/day of fish meal were equivalent to 700 of raw and 800 g./pig/day of cooked silage. The pigs receiving the silages had better growth rate and efficiency of food conversion, but their meat had a fishy taint and smell.

Sperling, Albrecht and Jahn (217) obtained as good results with their dried de-fatted herring silage as with herring meal. Provided the silage was withdrawn 4 weeks before slaughter, the carcass quality was good. The authors obtained good results also with a mixed silage consisting of 3 parts herring residues, 1 part streptomycin mycelia and 1 part animal blood.

Haskell *et al.* (91) studied the flavour of meat from pigs fed on rations with fish silage, and compared it with that from pigs fed maize soya bean rations, using the scores from a taste panel and the thiobarbituric acid test. A moderate off-flavour, sufficient to make the meat undesirable to the consumer was detected by the panel in the meat from pigs fed fish silage. This off-flavour was greater in the fat than in the lean parts. The intensity of the off-flavour was not affected by removal of the fish silage from the ration, when the pigs reached 170 lb. liveweight.

Clausen *et al.* (46) conducted a series of experiments in order to establish the effect of herring silage on carcass quality. They used older pigs (purchased from slaughter houses) and fed herring silage for periods of different lengths, followed by periods without silage before slaughter. No clear-cut results were obtained because of variation from one test to another; but the condition of the animal at the start of the feeding period, the level of feeding and even season of the year tended to affect the severity of the adverse effects on carcass associated with the feeding of the herring silage.

Fish products for breeding stock and baby pigs

Although in some countries fish meal is used extensively in rations for breeding pigs (gilts, sows and boars) with satisfactory results, there is very little experimental evidence on which one could base quantitative recommendations or make comparisons with other protein supplements. The few results that have been reported point clearly to the need of directing research efforts to this rather neglected field.

Wowra (247) reported that herring meal with a high oil content is a satisfactory protein supplement in rations for pregnant and lactating sows.

Boaz (20, 21) has shown that sows kept on grass do not benefit from rations containing a high-protein supplement. In another experiment, with sows kept indoors, a rather puzzling result was obtained: namely, that addition of 7½ per cent fish meal to the ration had no effect on the performance of the sows, but that 15 per cent appeared to be beneficial when judged by the number of pigs born, the number alive at 3 weeks, the number weaned, and by the weaning weights.

Hennig (95) found no difference in value between protein supplements of animal and vegetable origin in sows rations, and Barber *et al.* (12, 13) reported no difference in vitamin B_{12} content of sows colostrum and milk fed rations supplemented either with fish meal or with soya bean meal.

A recent report on the value of fish silage for sows is that of Pecht (181) who fed herring silage to sows with good results. On the other hand Clausen *et al.* (44) obtained worse results with herring silage than with rations supplemented with a mixture of fish meal and meat and bone meal. The losses of piglets and weight at weaning were adversely affected. An interesting feature of this test was a comparison of herring silages with different pH values (2 and 4).

Krider *et al.* (133) found benefits associated with the addition of 3–6 per cent of condensed fish solubles to a corn-soya bean ration for pregnant and lactating sows; but Gard, Terrill and Becker (83) found no benefit on gestation or lactation from addition of 3 per cent menhaden fish solubles to purified rations for sows.

Gage *et al.* (82) reported that fish solubles at increasing levels (0–6 per cent) produced a linear improvement in 4-week gain and feed conversion of baby pigs.

There is even less evidence on the value of fish meal as an ingredient of creep feeds for suckling pigs, though it is generally recognized that it is a useful protein supplement for very young pigs.

Stahl, Harring and Kühler (220) reported that when added at 20 per cent of the creep feed white fish meal gave better results than cod meal.

Nigul (171) found that replacement of whole or skim milk by fish meal in creep rations had no effect on the growth rate of the pigs.

In recent years, the problem of artificial rearing of pigs has attracted much attention. Most of the formulae used for sow's milk replacers contain milk products as the main source of protein. However, in order to make the rations more economical, attempts have been made to replace the milk products by fish meal. Lucas, Calder and Smith (152), for example, obtained satisfactory results with pigs artificially reared from 9 lb. liveweight on rations in which half of the skim milk was replaced by white fish meal. When all of the skim milk was replaced, the performance was not quite so good.

Miscellaneous

In this brief chapter a few papers are mentioned which deal with fish products and problems of rather unusual nature:

Kernot and Speer (120) found "sea bream" meal (high in fat content) superior to best quality white fish meal as a supplement to rations of growing pigs.

Lehmann (146) reported that lobster meal can be used as a protein supplement for pigs.

Wo (236) found that crab meal containing 38 per cent crude protein 7 per cent oil and 40 per cent ash has no value as a protein supplement.

Angel (4) obtained satisfactory results with shrimps fed at 5–20 per cent of the ration.

Marschall and Davis (161) have suggested that shark meal (which may contain up to 88 per cent crude protein, though the average is 78·1 per cent) is an acceptable source of protein for pig rations. Fed at levels of 5·9 to 14 per cent of the ration, shark meal was found equal to a skim milk supplement. It did not produce any off-flavour in meat.

Lovern and Godden (151) suggested that the most promising of the various forms of "waste products" which are still discarded in British fisheries is the guts—mainly stomachs and intestines, which usually are thrown overboard by trawlers. Such material is capable of giving a yield and type of meal similar to that obtained from the usual fish offal. A meal with 10 per cent moisture can have the following composition: crude protein 69·0, oil 4·5, ash 8·2 per cent.

Kudryavtsev (140) found that Dolphin and "midi" (*Mytilus edulis* mussel) meal, added as a supplement to pig rations, increased growth rate and efficiency of food utilization.

Krupka, Pliszczynski and Skulmowski (139) were interested in the Norwegian fish paste containing 46·37 per cent dry matter, 32·96 per cent crude protein, 3·97 per cent oil and 9·45 per cent ash, and established its digestibility coefficients for organic matter, 83·39, and crude protein 78·68.

Kraack (1956) used as a protein supplement in rations for sows a meal prepared from fish liver residues after extraction of oil, which contained 17·2 per cent crude protein and 18·3 per cent oil. The test involved only 3 gilts.

Dammers (58) found eel meal of similar value to herring meal as a supplement to cereal rations for growing pigs.

Hvidsten (111) and Hvidsten and Husby (112) have shown that preservation of herring meal by nitrite did not have any adverse effects on pigs receiving up to 260 g./pig/day. An extensive bulletin on the subject of preservation of herring meal with sodium nitrite has been published in Norway by Heen *et al.* (93).

Homb (99) found no significant difference in performance of pigs or in carcass quality, when comparing herring meal stored either in silos or in sacks.

Englert *et al.* (70) described a "fish meal disease" in pigs caused apparently by feeding 5–8 per cent of normal fish meal (cod meal). They gave full chemical details of the suspected meal; but neither these nor full microscopical and bacteriological examinations provided a clue to explain the condition.

Whale products

When considering protein supplements for pigs, it has always been a matter of controversy whether to classify whale products together with fish products. To make this review complete a few notes are included on the feeding of whale products to pigs.

Whale-meat meal of good quality is accepted as a valuable source of nutrients for pigs, particularly of protein. The variation in composition can be very great, and one should beware of generalizations. The differences in composition are mainly due to the method of processing adopted. Pritchard and Cawthorne (188) give details of composition of samples representing the range of whale meat meals used as feedingstuff. Although no official grading exists, whaling companies and merchants designate whale meat meals with protein content of 80–85 per cent as grade A, those with 40–65 per cent as grade B, and meals derived mainly from bone as grade C.

The following values quoted from Nehring (169) are instructive:

	Dry matter	*Cr. protein*	*Cr. oil*	*N-free extr.*	*Ash*
Whale meat meal	90·6	74·0	10·5	1·5	4·0
Whale meat and bone meal	92·0	53·7	12·0	1·5	24·8

	Digest. coefficients		*Digestible nutrients*	
	Organic matter	*Cr. protein*	*Cr. protein*	*Total*
Whale meat meal	90	91	68·3	80·8
Whale meat and bone meal	67	76	40·8	55·5

Woodman and Evans (243–244) used whale meat meal of the following composition: moisture, 5·58 per cent, crude protein 87·75 per cent (of which 82·56 per cent was true protein), oil 3·46 per cent, N-free extractives 1·15 per cent, ash 2·06 per cent (CaO 0·05 per cent, P_2O_5 0·90 per cent, Cl_2 0·03 per cent). The digestibility coefficient established on pigs were as follows: for protein 87·8, oil 97·0. These details highlight the main features of whale-meat meal as a supplement for pigs: very high in protein, low in fat, and very low in minerals.

Golding and Morris (87) fed pigs up to 100 lb. live-weight on whale-meat flakes and found them as good as, or slightly better than, a supplement of white fish meal. When given to older pigs (up to bacon weight) the whale-meat meal gave slightly inferior results. There was no taint in the carcass.

Schmidt, Kliesch and Giersberg (208) found whale-meat meal a satisfactory protein supplement for pigs, while Marsh and Kanagaratnam (162) considered it unsuitable for rations of weaner pigs.

Yagovkin (249) considered the supplementary value of whale-meat meal as about equal to that of sunflower meal.

Husby (109) and later Hvidsten and Husby (113) reported that whale-meat meal gave as good results as herring meal when fed as a supplement to rations of growing pigs. On the other hand Malkomesius (156), Richter and Brüggeman (195) and more recently Dammers (58) obtained better results with herring meal than with whale-meat meal.

Hewitt (96) used whale solubles at 8 per cent as a source of protein in cereal rations, and found that the growth rate of pigs and their efficiency of food utilization was not as good as that of pigs receiving rations supplemented with meat meal. The whale solubles consisted of a black viscous liquid with 45–50 per cent dry matter, 42–48 per cent crude protein, 1–2 per cent oil and 4–5 per cent ash. On the other hand Alden, Sangster and Jones (1) and Hope, Weston and Garstone (105) found that condensed whale solubles can satisfactorily replace meat meal in rations of pigs.

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PRELIMINARY REPORT ON THE USE OF FRESH ANCHOVY (Engraulis ringens) IN PIG FEEDING

by

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Fish meal is produced in Peru in large quantities for the animal industry (600,000 MT, 1960). Up to now, however, no attempt has been made there to use fresh anchovy in feeding chickens and pigs.

However, the large difference in cost between the dry matter of fresh anchovy and that of fish meal indicated the necessity of studying the use of fresh anchovy in the feeding of chickens and pigs. Work at the Agrarian University has been initiated to evaluate the possibilities of using *Engraulis ringens* in the ration of pigs raised near fishing ports.

In the first test 12 baby pigs were separated in two lots of six each. Lot A was given a ration made exlusively of fresh anchovy, and Lot B a ration composed of 50 per cent fresh anchovy and 50 per cent balanced concentrate for pigs. The pigs were weighed weekly, and kept under observation for 2 months. At the beginning the animals were reluctant to consume the fresh anchovy, but became accustomed to it quite rapidly. In Lot A the general state of health, physical condition and the rate of growth were poor; whereas the animals of Lot B were in much better physical condition and had a better rate of growth.

Since the pigs failed to show good results with anchovy alone, the animals of Lot A were classified in two sub-lots; one was incorporated into Lot B, and the other made into Lot C with a new group of six baby pigs. Lot C was fed with equal quantities of anchovy and sweet potato, one of the most inexpensive sources of energy on the coast of Peru. The results of these treatments B and C were similar, although the rates of weight gain of both groups were moderate. From the economical point of view, however, pigs consuming the ration of anchovy and sweet potato made the cheapest gains of all.

A second trial involving 36 pigs was carried out, using treatment B and C against a control standard ration.

The animals were weighed at weekly intervals and the amount of food consumed was recorded. Observations were made on body-conformation and general appearance. Statistical analysis of the weight gains were carried out. Blood samples were taken to determine hemoglobin, hematocrit and R.B.C. (red blood count).

The pigs were kept until they reached approximately 100 kg. of weight; cost studies were carried out to establish the economical significance of the use of anchovy in some pig rations.

The pigs of Lot C, fed on anchovy and sweet potato, were placed on the control ration during the last 30 days of experiment. They were slaughtered 5, 10, 15, 20, and 25 days after being changed from ration C to the control ration. The effect of short periods on a fish-free diet was studied to ascertain how long a period is necessary to remove the fish flavor from the meat.

At the end of the experiment the pigs of Lots B, C and control were slaughtered and the carcass quality evaluated.

Meat cuts were used to establish meat quality, i.e. tenderness, color, flavor. (Special attention was paid to fish flavor).

Samples of liver, kidney, heart and the ham were saved for histological studies.

The results of these experiments allow us to conclude the following: (1) Anchovy can be used successfully as an ingredient of pig rations; (2) The use of anchovy in pig rations lowers the cost of pork production; (3) More research is needed to elaborate better pig rations, using anchovy as the main component.

COMPTE RENDU PRELIMINAIRE SUR L'UTILISATION DE L'ANCHOIS FRAIS (*ENGRAULIS RINGENS*) DANS L'ALIMENTATION DU PORC

Au Pérou, la farine de poisson est fabriquée en grande quantité pour l'industrie animale (600.000 tonnes en 1960). Jusqu'à présent, il n'y a eu au Pérou aucune tentative pour utiliser l'anchois frais dans l'alimentation des poulets et des porcs.

Cependant, la grande différence entre le prix de la matière sèche de l'anchois frais et celui de la farine de poisson montre la nécessité d'étudier l'emploi de l'anchois frais dans l'alimentation des poulets et des porcs. L'Université agraire a entrepris une étude pour évaluer les possibilités d'utiliser l'*Engraulis ringens* dans les rations des porcs élevés près des ports de pêche.

Dans la première expérience, on a séparé 12 porcelets en deux groupes de six. Le lot A a été nourri d'une ration exclusive d'anchois frais; et le lot B, d'une ration composée de 50% d'anchois frais et de 50% de concentré équilibré pour porcs. Les porcelets étaient pesés chaque semaine, et gardés en observation durant deux mois. Au commencement, les animaux montraient une certaine répugnance à consommer les anchois frais, mais ils s'en accoutumaient assez rapidement. Dans le lot A, l'état général de santé, la condition physique et le taux de croissance étaient médiocres, alors que dans le lot B les animaux étaient en bien meilleure condition physique et montraient un meilleur taux de croissance.

Comme les porcs ne pouvaient atteindre de bons résultats avec les seuls anchois, les animaux du lot A ont été séparés en 2 sous-groupes; l'un a été incorporé au lot B, et l'autre a fourni le lot C avec un nouveau groupe de six porcelets. Le lot C a été alimenté avec des quantités égales d'anchois et de patates douces, l'une des sources d'énergie la moins chère de la côte du Pérou. Les résultats de ces régimes B et C ont été comparables, quoique le taux de gain de poids dans les deux lots ait été modéré. Du point de vue économique, cependant, les porcs consommant la ration d'anchois et de patates douces ont donné les gains de poids les moins chers de tous.

Une deuxième expérience mettant en jeu 36 porcs a utilisé les régimes B et C à côté d'un régime-témoin standard. Les animaux étaient pesés à intervalles hebdomadaires, et la quantité de nourriture consommée, notée. Les observations portaient sur la conformation du corps et l'apparence générale. On a effectué une analyse statistique des gains de poids. On a prélevé des échantillons de sang pour la mesure de l'hémoglobine, l'analyse à l'hématocrite et la numération érythrocytaire.

Les porcs ont été élevés jusqu'au poids approximatif de 100 kg.; on a conduit des études de prix pour établir l'économie de l'emploi des anchois dans quelques rations pour porcs.

Les porcs du deuxième régime, consommant des anchois et des patates douces, ont été mis au régime-témoin durant les 30 derniers jours de l'expérience. Ils ont été abattus 5, 10, 15, 20 et 25 jours après être passés du régime C au régime-témoin. On a étudié l'effet des courtes durées de régime sans poisson pour préciser le temps nécessaire à la disparition de l'odeur de poisson dans la viande.

A la fin de l'expérience, les porcs des lots B et C et ceux du régime-témoin ont été abattus, et l'on a évalué la qualité de leurs carcasses.

Des tranches de viande ont servi à établir la qualité de la viande: c'est-à-dire la tendreté, la couleur, la saveur (avec une attention particulière au goût de poisson).

Des échantillons de foie, de reins, de coeur et de jambon ont été recueillis pour les études histologiques.

Les résultats de ces expériences nous permettent d'arriver aux conclusions suivantes: (1) les anchois peuvent être employés avec succès comme élément des rations pour les porcs; (2) l'emploi de l'anchois dans ces rations abaisse le prix de la production du porc; (3) des recherches plus étendues sont nécessaire pour élaborer de meilleures rations pour les porcs avec l'anchois comme composant principal.

INFORME PRELIMINAR SOBRE EL EMPLEO DE ANCHOVETA FRESCA (*ENGRAULIS RINGENS*) EN LA ALIMENTACION DE CERDOS

Aunque en Perú se fabrican grandes cantidades de harina de pescado para la industria pecuaria (600.000 tons. métricas en 1960), hasta ahora no se ha intentado emplear la anchoveta fresca en la alimentación de pollos y cerdos en ese país.

Sin embargo, la gran diferencia en el coste entre la materia seca de la anchoveta fresca y la harina de pescado pone de relieve la necesidad de estudiar el empleo de aquélla en la alimentación de pollos y cerdos. En la Universidad Agraria se ha iniciado una investigación para evaluar las posibilidades de emplear *Engraulis ringens* en la ración de cerdos criados cerca de puertos pesqueros.

En el primer ensayo, 12 lechones se dividieron en dos grupos de 6 cada uno. El grupo A fue alimentado con una ración compuesta exclusivamente de anchoa fresca; el grupo B, con una ración compuesta de un 50% de anchoa fresca y un 50% de un concentrado equilibrado para cerdos. Estos se pesaron semanalmente, y se estudiaron durante dos meses. Al principio, se mostraban reacios a consumir la anchoa fresca, pero se acostumbraron a ella rápidamente. En el grupo A, el estado general de salud, condición física y velocidad de crecimiento eran malos, en tanto que los animales en el grupo B estaban en mucho mejor estado físico y crecían más rápidamente.

Debido a la incapacidad de los cerdos de rendir adecuadamente alimentándose sólo de anchoas, los animales del grupo A fueron clasificados en dos subgrupos: uno que se incorporó al grupo B, y otro que constituyó el grupo C con otros 6 lechones neuvos. El lote C se alimentó con cantidades iguales de anchoa y camote, una de las fuentes de energía más baratas de la costa del Perú. Los resultados de los tratamientos B y C fueron análogos; y aunque los ritmos de aumento de peso de ambos grupos fueron moderados, desde el punto de vista económico los cerdos que consumían la ración de anchoveta y camote hicieron los progresos más baratos de todos.

Se realizó un segundo ensayo con 36 cerdos empleando los tratamientos B y C y una ración testigo normal. Los animales se pesaron semanalmente, y se registró la cantidad de alimentos consumida. Se hicieron observaciones de la conformación y aspecto general del cuerpo. Se realizaron análisis estadísticos de los aumentos de peso, y se obtuvieron muestras de sangre para determinar la hemoglobina, hematóclito y recuento de los hematíes.

Los cerdos se criaron hasta que alcanzaron unos 100 kg. de peso; se llevaron a cabo estudios de costes para establecer la significación económica del empleo de anchoveta en algunas raciones.

Los cerdos alimentados con la segunda ración, consistente en anchoveta y camote, se pusieron en la ración testigo durante los últimos 30 días del experimento. Se sacrificaron a los 5, 10, 15, 20 y 25 días después de pasar de la ración C a la testigo. Se estudió el efecto que tiene una ración sin pescado durante cortos periodos, para determinar cuánto tiempo hace falta para que desaparezca el sabor a pescado de la carne.

Al terminar el experimento, los cerdos de los grupos B, C y testigo se sacrificaron y se evaluó la calidad de las canales.

Se emplearon diversos trozos para establecer la calidad de la carne, a saber: ternura, color y sabor (se prestó especial atención al sabor a pescado).

Se obtuvieron muestras de hígado, riñón, corazón y jamón para efectuar estudios histológicos.

Los resultados de estos experimentos permiten llegar a las conclusiones siguientes: (1) la anchoveta da resultados satisfactorios como ingrediente en la alimentación de cerdos; (2) el empleo de anchoveta en la alimentación de los cerdos reduce el coste de su producción de carne; (3) se tienen que efectuar más investigaciones para preparar mejores raciones para cerdos empleando anchoveta como el principal componente.

DISCUSSION

On the paper submitted by Dr. Braude, **Dr. I. W. Lane** (U.S.A.) observed: Both in the United States and in Peru fish meal is a primary product for the food industry, not a by-product.

Dr. R. Braude (U.K.): Lane is correct. However, in fairness to fish meal manufacturers in other countries one should add that a good quality fish meal can also be produced from a high proportion of offal, provided that some fish flesh is added.

Dr. G. Borgström (U.S.A.): It appears important to clarify certain basic concepts. The frequent comparisons made between fisheries and agriculture overlook the fundamental differences between them. Efficiency of sea-animals does not approach that of land-animals, but its cost to us is markedly lower. If we consider fish cultivation, the situation may be competitive. From this standpoint, carp production is economically superior to pig production. The question is, however: are we utilizing fishery products efficiently, when we use them for animal production? The answer is: it is more efficient to use fishery products directly. If the current production of fish be utilized in the Caribbean, these people's protein consumption could be raised to a level equal to that in the United States. I am certain that we shall see important changes in fishery products utilization.

Dr. H. L. A. Tarr (Canada): Work in our laboratory indicates that fish meal may be heated to 300°F for 3 hours before protein quality is lowered, while heating to 300°F for shorter time may improve the nutritive value of fish meal. I recommend that this point be investigated further.

Dr. C. Byrd (U.S.A.): We have found that the only way to destroy the unknown growth factor is to ash the fish meal, as it is not destroyed by routine handling.

Dr. R. Braude (U.K.): Results of our biological studies indicate that technological treatment of fish meals may not necessarily affect the quality of the product in the way intended.

Dr. O. R. Braekkan (Norway): From our biological tests, it was found that these tests may be improved by better evironmental control (i.e. timed feeding; timed feed mixing, etc.). Therefore, both animal response and experimental conditions must be discussed before experimental results can be evaluated.

Dr. A. M. Leroy (France): The interpretation of results of any feeding experiment requires a thorough knowledge of all experimental conditions. The following is an example of how a poor-quality fish meal, as determined by Dr. Carpenter's lysine test, may be evaluated incorrectly: A diet of potatoes and clover meal may result in a good amino acid distribution. Thus, any addition of the above fish meal to this basic diet could give satisfactory results, even though the fish meal itself was of poor quality. It is important therefore to study all methods and procedures involved in an experiment.

Mr. F. Bramsnaes (Denmark): Dr. Braude stated that silage is of high quality only when made from lean fish. This is not always true. If the greater part of the oil from fatty fish is removed, silage of high quality can be made. However, cooking is not the best way to remove the fat, as some of the nutrients may be destroyed. Although various methods are available, a cold enzymatic partial breakdown is preferable before the oil is removed. In many of the experiments with fish silage, a residual flavour is found in the pig's flesh. To eliminate this problem a smaller quantity of silage should be fed.

Dr. R. Braude (U.K.): In reply to Dr. Braekkan's comments, all of our tests have been conducted with an attempt

to control all the environmental and experimental conditions you have mentioned. The only difference between our various experimental stations was the pig supply and the climatic environment. The only reasonable way to test protein supplements is to work at marginal protein levels; for, as you know, our current standards contain very wide safety margins. Personally, I have little knowledge of fish silage. However, after an objective review of the literature, it appears that considerable work needs to be conducted on silage for pigs.

On the paper submitted by Dr. Bacigalupo, Dr. L. E. Ousterhout (U.S.A.) asked: Could vitamins of the B group have been responsible for the differences in rate of gain found by Dr. Bacigalupo?

Dr. A. Bacigalupo (Peru): As a side test, " slow gainers " were given all vitamins except E (which was in short supply) without noticeable effect.

Dr. T. Kaneda (Japan): Are any exact data on iodine numbers available?

Dr. A. Bacigalupo (Peru): Lot 1 was 48·5; Lot 2, 62; and Lot 3, 68.

Dr. D. G. Snyder (U.S.A.): Do anchovies contain thiaminase?

Dr. A. Bacigalupo (Peru): Information on the presence of thiaminase in anchovies is believed to be unavailable at this time.

Dr. A. M. Leroy (France): Was pH level of the meat determined? Certain rations tend to lower the pH of meat; and, if the pH is too low, the meat is rejected for some uses. The pictures showed a good proportion of fat to lean; however, the paleness of the meat suggests anaemia.

Dr. A. Bacigalupo (Peru): The pH of the meat was determined, but such data are not available here. Perhaps a slight anaemia may have been present, and an iron supplement might have given a good response; this may be an answer to one of our problems.

Dr. L. E. Ousterhout (U.S.A.): Herring meals on the West Coast resisted heat damage; but menhaden meals are definitely susceptible to such damage.

Dr. K. J. Carpenter (U.K.): Colour changes appear to be related to disappearance of ribose nuleic acid. Studies of menhaden meal, in comparison with other meals, appear to offer interesting possibilities.

Dr. J. W. Jebsen (Norway): Perhaps, reduction of available lysine of the fish meal may have accounted for some of the results observed by Carpenter.

Dr. K. J. Carpenter (U.K.): It was pointed out by Morrison (Canada) that the solvent at low temperatures does not damage the meal. But, when the solvent is drawn off at an elevated temperature, damage undoubtedly can occur.

Section 2c: POULTRY NUTRITION

FISH AND FISHERY PRODUCTS IN POULTRY RATIONS

by

J. BAELUM

Fish meal and condensed fish solubles are by far the most important feedingstuffs of fish origin. Commercial fish meals are manufactured from various fish or waste products from the fish industry; the type of the raw material and the method of manufacture greatly influences the value of the product as feed for poultry. The chemical composition of the fish meal depends on the raw material employed, whilst the factory treatment influences its protein value. It has been reported that drying fish meal at relatively low temperatures gives a better product than results from high temperature drying.

With these reservations, fish meal may be considered as the best source of high quality protein, containing considerable amounts of all the essential amino acids, though not particularly high in methionine.

Fish meal has been a common ingredient in poultry rations as long as rational feeding of laying birds and chicks has been practised. Although the protein requirements of poultry can be largely satisfied by vegetable protein, experience has shown that higher egg production from laying birds and better growth rates with chicks are obtained when feeds of animal origin, especially fish meal, are included in the ration.

A partial explanation of the special nutritive value of fish meal was obtained with the discovery of the "animal protein factor", of which vitamin B_{12} was later found to be an effective part. Numerous investigations have shown, however, that the specific effect of fish meal is not due to its content of vitamin B_{12} alone. Other unidentified growth factors appear to exist in fish meal and other fish products, although a specific effect of this type has not been found in all cases.

Even though fish meal protein is considered to be of superior feeding value and is difficult to replace, it is used in relatively small amounts of 3–5 per cent, since vegetable protein is cheaper.

Fish meal does, however, have some undesirable properties. If fed in large amounts, it may induce a fishy flavour in poultry meat, and to a lesser extent in eggs. White fish meal has been reported occasionally to cause a significant depression in the hatchability of fertile eggs. Furthermore, fish meal from some countries has been shown to be infected with salmonella bacteria, and thus to spread this disease in the poultry flocks.

Owing to the high content of vitamin B_{12} condensed fish solubles are used as a supplement in many vegetable chicken diets. Various tests have shown that the supplementation of a vegetable diet (corn and soybean meal ration) with condensed fish solubles increases the growth rate of chicks. No less remarkable are the results of American trials which show a similar, but smaller, effect when supplementing feedingstuffs with the ash of fish solubles and dry whey. These inorganic constituents produced a highly significant increase in growth.

In Scandinavian countries condensed fish solubles are not used as a special ingredient in the ration, but are included in the fish meal, whereby it becomes rich in vitamin B_{12}. Herring meal, supplemented with condensed fish solubles, is known under the name of "whole meal" and is considered to be the best fish meal on the market.

No doubt it would be in the interest of the poultry producers and the feed manufacturers (and probably stimulate the demand for fish meal) if the commercial meals were standardized to some extent, showing less variability in the chemical composition and the nutritive value; fish meal may be expected to be absolutely free of pathogenic bacteria. The salt content of the product must be low; if it exceeds a certain low limit, the content must be stated.

If the substances which produce the fishy flavour in poultry meat and eggs could be economically extracted, the amount of fish meal in poultry rations could be increased without risk of off-flavour in meat and eggs; but it is not likely that fish meal will ever be able to compete in price with soybean meal.

POISSON ET PRODUITS DU POISSON DANS L'ALIMENTATION DE LA VOLAILLE

La farine de poisson et les solubilisés concentrés de poisson sont de loin les aliments les plus importante issus du poisson. Les farines commerciales de poisson sont fabriquées depuis divers poissons ou divers déchets de l'industrie du poisson, et la valeur du produit destiné à l'alimentation de la volaille est beaucoup influencée par le type de matière première et la méthode de fabrication. La composition chimique de la farine de poisson dépend de la matière première employée, alors que le traitement en usine influence la valeur protéique. On a signalé que la farine de poisson séchée à des températures relativement basses donne un produit meilleur qu'avec un séchage à haute température.

Sous ces réserves, la farine de poisson peut être considérée comme la source la meilleure de protéines de haute qualité, contenant des quantités considérables de tous les acides aminés essentiels, quoiqu'avec une teneur qui ne soit pas particulièrement haute en méthionine.

La farine de poisson est un élément commun des rations pour la volaille depuis qu'on pratique une alimentation rationnelle des poules pondeuses et des poulets. Bien que les exigences protéiques de la volaille puissent être largement satisfaites par des protéines végétales, l'expérience a montré qu'on obtenait une production d'oeufs plus élevée des poules pondeuses et de meilleurs taux de croissance chez les poulets en incluant dans leur ration des aliments d'origine animale et, spécialement, de la farine de poisson.

On a trouvé une explication partielle à la valeur nutritive particulière de la farine de poisson en découvrant le "facteur protéique animal", dans lequel on a trouvé ultérieurement que la vitamine B_{12} jouait un rôle effectif. Cependant, de nombreuses recherches ont montré que l'effet spécifique de la farine de poisson n'est pas dû à sa seule teneur en vitamine B_{12}. D'autres facteurs de croissance non identifiés semblent exister dans la farine de poisson et dans d'autres produits du poisson, quoiqu'un effet spécifique de ce genre n'ait pas été trouvé dans tous les cas.

Bien que les protéines de farine de poisson soient considérées de valeur alimentaire supérieure et d'un remplacement difficile, on n'en utilise que de faibles quantités, de 3% à 5%, car les protéines végétales sont moins chères.

La farine de poisson peut présenter toutefois quelques propriétés désavantageuses. Donnée en grandes quantités, elle peut amener la chair de poulet et, dans une mesure moindre, les oeufs, à sentir le poisson. On a signalé que la farine blanche de poisson provoque occasionnellement une diminution notable dans le taux d'éclosion des oeufs fertiles. En outre, on a montré que la farine de poisson venant de certains pays était contaminée de bactéries Salmonella et répandait ainsi cette maladie dans les poulaillers.

Par suite de sa haute teneur en vitamine B_{12}, les solubilisés condensés de poissons sont utilisés comme supplément dans beaucoup de régimes végétaux pour les poulets. Des essais divers ont montré que la supplémentation d'un régime végétal (ration de farine de maïs et de soja) avec des solubilisés condensés de poisson augmentait le taux de croissance des poulets. Les résultats des essais américains, qui ont démontré un effet semblable mais plus faible d'une supplémentation des aliments avec de la cendre de solubilisés de poisson et du petit-lait sec, sont aussi remarquables. Ces constituants inorganiques ont produit une augmentation très notable de la croissance.

Dans les pays scandinaves, les solubilisés condensés de poisson ne sont pas utilisés comme ingrédient particulier des rations, mais sont inclus dans la farine de poisson qui s'enrichit ainsi en vitamine B_{12}. La farine de hareng supplémentée avec des solubilisés condensés de poisson est connue sous le nom de "farine entière", et considérée comme la meilleure farine de poisson disponible sur le marché.

Il n'y a pas de doute qu'il serait de l'intérêt des éleveurs de volaille et de celui des fabricants d'aliments, tout en stimulant probable-

ment la demande pour la farine de poisson, que les farines du commerce soient normalisées dans une certaine mesure et varient moins dans leur composition chimique et leur valeur nutritive; on doit demander à la farine de poisson d'être absolument nette de toutes bactéries pathogènes. La teneur en sel du produit doit être faible, et elle doit être indiquée si elle surpasse une certaine limite basse.

Si les substances qui provoquent une saveur de poisson dans la chair de volaille et les oeufs pouvaient être extraites d'une façon économique, la quantité de farine de poisson utilisée dans les rations pourrait être augmentée sans risque d'odeur désagréable dans la chair et les oeufs; mais il est peu probable que la farine de poisson puisse jamais entrer en compétition avec la farine de soja en considérant leur prix.

EL PESCADO Y LOS PRODUCTOS PESQUEROS EN LA ALIMENTACION DE LAS AVES

La harina y los solubles condensados de pescado son, con mucho, los piensos más importantes de origen pesquero. Las harinas de pescado del comercio se fabrican a partir de varios pescados o desechos de su industrialización, y la clase de materia prima y método de manufactura influyen mucho en el valor del producto como alimento para aves. La composición química de la harina de pescado depende de la materia prima empleada, y la manera en que ésta se trate en la fábrica influye en su valor proteico. Se ha informado que secar la harina de pescado a temperaturas relativamente bajas da un producto mejor que una desecación a temperaturas altas.

Con estas reservas, la harina de pescado puede considerarse como le mejor fuente de proteínas de alta calidad, con un considerable contenido de todos los aminoácidos esenciales, aunque sin un índice particularmente elevado de metionina.

La harina de pescado ha sido un ingrediente común en las raciones de las aves desde que se practica la alimentación racional de las gallinas ponederas y de los pollos. Aunque las necesidades de proteína de los pollos pueden satisfacerse en gran parte con proteínas vegetales, la experiencia demuestra que se logra una mayor producción de huevos de gallinas ponedoras y un mayor crecimiento de los pollos cuando se adicionan a la ración piensos de origen animal, especialmente harina de pescado.

Se logró una explicación parcial del valor nutritivo especial de la harina de pescado con el descubrimiento del "factor proteico animal", en el que posteriormente se encontró que la vitamina B_{12} desempeñaba un papel positivo. Sin embargo, numerosas investigaciones han demostrado que el efecto específico de la harina de pescado no se debe exclusivamente a su contenido de vitamina B_{12}. En la harina y otros productos de pescado parecen existir otros factores de crecimiento no identificados, aunque no en todos los casos se ha observado un efecto específico de este género.

Aunque las proteínas de la harina de pescado se consideran como de valor alimenticio superior y difícil de substituir, se emplea en las cantidades relativamente pequeñas de 3% a 5%, porque las proteínas vegetales son más baratas.

Sin embargo, la harina de pescado tiene algunos inconvenientes. Si se emplea en grandes cantidades, puede dar sabor a pescado a la carne de los pollos y, en menor grado, a los huevos. Se ha indicado que la harina de pescado blanco provoca ocasionalmente una disminución sensible en la proporción de nacimientos de huevos fértiles. Además, se ha demostrado que la harina de pescado de algunos países está contaminada con bacterias Salmonella y propaga esta enfermedad por los gallineros.

Debido al elevado contenido de vitamina B_{12}, los solubles de pescado condensados se emplean como complementos en muchos regimenes vegetales para pollos. Varios ensayos han demostrado que si una alimentación a base de vegetales (harina de maíz o de soja) se complementa con solubles de pescado condensados, aumenta la velocidad de crecimiento de los pollos. Son notables los resultados de ensayos norteamericanos que muestran un efecto análogo, pero más débil, cuando los piensos se complementan con la ceniza de solubles de pescado y de suero lácteo seco. Estos constituyentes producen un aumento muy notable de crecimiento.

En los países escandinavos los solubles de pescado condensados no se emplean como ingredientes particulares de las raciones, pero se incluyen en la harina de pescado, que se enriquece así de vitamina B_{12}. La harina de arenque, con un complemento de solubles de pescado condensados, recibe el nombre de "harina entera" y se considera como la mejor harina de pescado que se encuentra en el mercado.

Es evidente que interesará a los avicultores y a los fabricantes de piensos (y probablemente estimulará la demanda de harina de pescado) si las harinas del comercio se normalizasen en cierta medida, y variasen menos la composición química y el valor nutritivo; se debe exigir que la harina de pescado esté absolutamente exenta de toda bacteria patógena. El contenido de sal del producto debe ser bajo; y, si excede de cierto límite reducido, debe indicarse cuál es éste.

Si las substancias que dan sabor a pescado a la carne de pollo y a los huevos pudieran extractarse económicamente, la cantidad de harina de pescado en la alimentación de las aves podría incrementarse sin peligro de olores desagradables en la carne y los huevos; pero no es probable que la harina de pescado pueda jamás competir con la de soja, debido a sus precios.

FISH meal and condensed fish solubles are by far the most important products of fish origin used in poultry feeds. Fish meal is manufactured by boiling, drying and grinding either whole fish or the offals of fish used for human consumption. The chemical composition of the meal will therefore vary, depending upon whether whole fish or fish waste is used as the raw material.

Fish meal manufactured from whole fish, especially herring, is rich in fat if the oil is not extracted, whereas fish meal of fish waste origin contains less fat, but often much mineral material.

In certain countries white fish meal is preferred to herring meal since a high fat content may make the meal rancid, and the oil may taint both meat and eggs. In Great Britain "white fish meal" is defined as a product containing not more than 6 per cent of oil, and not more than 4 per cent of salt, obtained by drying and grinding or by some other method of treating waste of whole fish. In Norway, where the production of fish meal is very important, distinction is made between herring meal and fish meal. Herring meal is manufactured exclusively from herring, and is a high quality feeding-stuff. Fish meal is manufactured from other types of fish, mainly cod and fish offal, and is not considered to be as valuable as herring meal. Usually herring meal contains more fat than fish meal. In Denmark fish meal containing 65–70 per cent of protein is called herring meal, whilst fish meal with a lower protein content is called fish meal. The rule does not apply in all cases.

As an example of the chemical composition of herring meal and fish meal, the following four analyses are given, standardized to 10 per cent water:

	Herring meal		*Fish meal*	
	1	*2*	*3*	*4*
Protein	70·5	68·0	56·6	51·2
Fat	4·5	9·1	2·4	13·7
N-free extract	0·2	1·0	1·8	3·0
Ash	14·8	11·9	29·2	22·1
Water	10·0	10·0	10·0	10·0

Herring meal No. 2 has a rather high fat content and is probably manufactured from fat herring. The fat content of fish meal No. 3 is low and the mineral content high, indicating that much fish offal (heads and bones) has gone into this product. Fish meal No. 4 is probably manufactured from fat industrial fish.

In practice very little distinction has been made between meals prepared from whole fish or from the waste of the fish industry. The term "fish meal", has been generally applied to the different products without distinguishing between the source of the material. In the following, the term fish meal will be used to describe fish meal with a high protein content and high biological value, unless otherwise stated. Aagren (17) gives the content of the three most important amino acids as follows:

Lysine	9·5 g. per 100 g. protein
Methionine	3·1 ,, ,, ,, ,, ,,
Cystine	0·9 ,, ,, ,, ,, ,,

The content of lysine and methionine is higher than that usually found in soybean meal, though the methionine content is no higher than that of sunflower seed meal. Furthermore, fish meal, and especially fish solubles, have a high content of the B-vitamins, including riboflavin and vitamin B_{12}. No vitamin A would be expected in fish meal; and in fish meal where the liver is not included, no vitamin D is found either. However, the mineral content is high, both herring meal and fish meal being good sources of calcium and phosphorus.

Feeding trials with fish meal

Fish meal has been used as an ingredient of poultry rations in most countries as long as rational feeding of hens and chickens has been practised. Numerous reports of trials with fish meal have been published. It is impossible to refer to them all in this paper, but mention may be made of the excellent literature revues of Menge, Combs *et al.* (30), Branion and Hill (9), Rasmussen *et al.* (39), and Lillie *et al.* (24, 26).

Early trials showed that feedingstuffs of vegetable origin rich in protein can satisfactorily make up a part of the protein in a diet for poultry; but these rations ought to contain a certain amount of protein of animal origin, usually fish meal, and meat and bone meal. The following results were obtained in a Danish experiment (1936) with laying birds, in which two rations, each containing 20 per cent crude protein, were tested, the one ration containing only vegetable protein, and the other containing 15 per cent fish meal and meat and bone meal:

	Vegetable protein	*Animal protein*
No. of eggs per hen, 10 months	126	153

Similar results were reported from trials in many other countries. As an example, a trial conducted by Heuser *et al.* (18) may be mentioned, where fish meal, solvent soybean oil meal, corn gluten feed, cottonseed meal, linseed oil meal, peanut oil meal and wheat germ meal were added to a basal mixture as protein concentrates. The addition of 3 per cent fish meal to the single vegetable protein concentrates increased the growth of all of them.

To obtain optimum growth and feed efficiency for chicks up to 8 weeks of age, the ration can derive its supplementary protein chiefly from soybean oil meal; but it should contain a minimum of 2–3 per cent of animal protein concentrates, such as fish meal, meat scrap or dried skim-milk. Similar results were obtained in a Danish trial (3) where the chickens were kept on build-up litter:

Herring meal, per cent *Soybean meal, per cent*	*0* *22*	*4* *15*	*8* *9*
No. of chickens	402	402	402
Weight, 87 days, g.	1315	1373	1392
Feed conversion	4·33	4·04	3·86

The vegetable ration containing soybean meal gave rather good results, but the 2 groups fed herring meal showed better growth and improved feed conversion.

Similar results were obtained with chickens (N.H. × W.L.) kept in batteries (4):

Fish meal, per cent *Soybean meal, per cent*	*0* *21*	*2* *18*	*4* *15*	*6* *12*
No. of chickens	300	300	300	300
Weight, 52 days, g.	487	487	518	570
Feed conversion	3·38	3·34	2·99	2·98

On replacing soybean meal with increasing amounts of herring meal, increased growth rates and better feed conversion were obtained with the chickens.

Characteristic for fish meal of good quality is the high protein content, which depends on the amount of ash in the meal. The protein has a high digestibility coefficient and a high biological value, thus making fish meal difficult to replace completely in poultry feeds. In general, fish meal is the best source of high quality protein.

Fish meal and antibiotics

Related to the growth stimulating effect of fish meal, the effect of feeding antibiotics to chicks is less when fish meal is included in the diet than on an all-vegetable ration. Fuller *et al.* (16) report: When streptomycin was fed in combination with vitamin B_{12} or fish solubles, the improvement in growth rate over that produced by these supplements alone was slight. Similarly Branion and Hill (9) reported that the percentage growth response of chicks to procain penicillin is lower if fish meal is included in the diet, but average growth is greater.

This is to be expected. The greatest percentage effect of antibiotics is obtained when the control group is growing slowly due to a deficient feed ration.

The protein quality of fish meals

The nutritive value of fish meal depends, not only on the type of raw material used in the manufacture, but also upon the method of processing; the drying process is especially important. Numerous trials have been performed to determine the nutritive value of commercial fish meals.

Record, Bethke, Wilder and Kennard (40) found that fish meals vary greatly in their nutritive value. Excessive drying temperatures affect the biological value. Also the nature of the original material affected the nutritive value. Rations containing fish meals, with the exception of flame-dried menhaden fish meal, were utilized more efficiently than those containing meat scraps. The shell-fish meal (crab and shrimp) were not utilized so efficiently as the other fish meal rations.

Wilgus, Norris and Heuser (47) reported that flame-dried fish meal was of inferior value. Rhian *et al.* (41) found that commercial dog-fish meals purchased on the open market had very little value as protein feeds for chicks.

March, Stupich and Biely (28) compared 8 samples of fish meal and meat meals, and reported the following protein index values which represent the nutritional value of the protein of the fish meal:

	Protein index	*Percentage of total N present in digestible protein*
Herring meal, vacuum-dried	83	86·5
Herring meal, flame-dried	69	72·3
Herring offal meal	81	85·0
Salmon offal meal	79	83·2

These figures indicate considerable variations in the nutritive value of the fish meals used.

Clandinin (11) studied the effect of methods of processing on the nutritive value of herring meals. Meals of equal nutritive value may be produced by different methods of drying; but meals dried at high temperature (220°F = 105°C) may be expected to be decidedly inferior in nutritive value to meals dried at lower temperatures or vacuum-dried meals. Liberation of essential amino acids by enzymatic hydrolysis is similar.

Nehring and Wünsche (32) gave the following "relative protein values" for various types of fish meal:

	Relative protein value
Herring meal No. 1 (standard)	100
Herring meal No. 11	110
Fish meal No. 5	100
Herring meal No. 14	68
Fish meal No. 2	64
Fish meal No. 3	67

The fish meals examined showed considerable variation in the protein values.

Tarr, Biely and March (45) found chick growth rates considerably slower with the rations containing commercial flame-dried herring meals than with the meals dried at low temperature. Supplementation of rations containing the commercial meals with a mixture of vitamins of the B-complex raised the nutritive value of the commercial meals to that of the low temperature meals.

MacIntyre (27) showed that commercial-grade fish meals produced in the maritime provinces vary considerably in growth-promoting quality for growing chickens, confirming observations made by many workers on fish meals produced in other regions. Growth rate on diets in which the different fish meals supplied approximately 40 per cent of the crude protein varied from 106 to 81 per cent of that on the control diet. Differences were noted between different brands of fish meal as well as between different batches of the same brand of meal produced at different times. Thus, brand name or registration number is no guarantee of uniform quality. The data presented suggests that the variation in growth is due to variation in the quality of the protein present in the fish meals.

Bender and Haizelden (5) examined 27 samples of commercial fish meals and deodorized fish flours intended for human consumption. Digestibility and net protein utilization was determined by rats. Biological value was calculated by dividing net protein utilization by digestibility. NPU ranged from 18 to 80, digestibility from 47 to 97, and biological value from 39 to 79.

Laksesvela (21) compared the growth of chicks receiving unheated herring meal or spontaneous heated herring meal:

Herring meal	*Gain (g.) after 2 weeks*
Unheated	39 ± 3·2
Heated	15 + 1·9

The chicks ate much less of the diet containing heated meal than they did of the diet with good meal. The spontaneous heating of herring meal to a dark brown colour changed the ratio of available amino acids to such an extent that it totally failed to sustain life. Chemical analysis showed a 40 per cent fall of "available lysine" in the sample. However, lysine could not be the most affected amino acid.

Finally Laksesvela (22) undertook trials with herring meal of high and low free fatty acid content fed to chickens, and concluded that the percentage content of the free fatty acids cannot be used as a basis for the evaluation of herring meal.

Condensed fish solubles

Numerous workers have investigated the supplementary effect of small amounts of animal protein feeds in diets containing vegetable proteins. When the "animal protein factor", of which vitamin B_{12} later proved to be the effective substance, was discovered in the U.S.A. in 1949, an explanation of the specific effect of feedstuffs of animal origin was suggested; namely that these feeds, and especially fish products, had a high vitamin B_{12} content.

Fish press water is obtained by hydraulic extraction of the oil. On evaporating press water, condensed fish solubles are obtained, the chemical composition being as follows (46):

Protein	33·5 per cent
Fat	4·0 " "
N-free extract	0·5 " "
Ash	12·0 " "
Water	50·0 " "

Lillie *et al.* (25) determined the B_{12} potency of some feedingstuffs and concentrates and report the following contents of vitamin B_{12}.

Fish solubles A	0·98 mg. per kilogram
Fish solubles B	0·75 " " "
Fish solubles C	0·39 " " "
Whale solubles	0·28 " " "
Liver meal	0·55 " " "
Herring fish meal	0·30 " " "
Norway fish meal	0·25 " " "
Meat and bone scrap	0·10 " " "
Whey, dried	0·03 " " "
Buttermilk, dried	0·02 " " "

Berry *et al.* (6) found that fish press water, fish liver meal, and animal liver meal appear to be three of the most satisfactory supplements to a corn and soybean oil meal ration.

Cravens and co-workers (14) reported that the addition of condensed fish press water was highly effective in supplementing a basal diet, composed of yellow corn, wheat by-products, meat scraps, soybean oil meal, minerals, fish oil and containing adequate riboflavin.

Lassen and Bacon (23) proved that, under the condition of the experiments, condensed fish solubles can be incorporated into a poultry ration with good results.

Wisman *et al.* (48) found results that may be indicated by the following figures:

	Vegetable basal diet	
	no animal protein	*5 per cent fish solubles*
Weight 4 weeks, g.	316	337
Feed : gain ratio	2·10	2·09

A consistent overall growth response was evident from fish solubles.

Unidentified factors in feeds of fish origin

The favourable influence of animal protein cannot, however, be attributed to the vitamin B_{12} content of these feeds alone. A great number of investigations indicate that fish solubles and other products of fish origin have an unidentified growth factor, different from vitamin B_{12}. This may be a question of the amino acid composition of the animal protein, since there is interaction between methionine and vitamin B_{12}. If the feed contains much methionine (which is seldom the case), vitamin B_{12} shows only little influence.

Heuser and Norris wrote (19): "A number of reports have appeared indicating that vitamin B_{12} was a complete substitute for fish products. The experience in this laboratory does not agree with these reports. The following results were found:

Supplement to vegetable protein ration	*Weight 8 weeks per cent*	*Microgram of B_{12} added per lb. of ration*
Crystalline vitamin B_{12}	100	6·4
Fish meal	107	2·0
Condensed fish solubles	112	0·6

The results show that animal protein feeds contain some as yet unknown nutritive factor. There is some evidence to indicate that some of the growth stimulus due to animal protein feeds can be obtained by the feeding of antibiotics".

Fuller, Carrick and Hauge (16) supplemented a vegetable basal ration of 57·5 per cent yellow corn and 38 per cent soybean oil meal plus vitamins and minerals with vitamin B_{12}, APF or fish solubles. The chicks were depleted for 2 weeks.

Supplement	*None*	*B_{12}*	*APF*	*Fish solubles*
Gains 2–8 weeks, g.	616	785	791	805

With one exception condensed fish solubles have produced greater growth in chicks than vitamin B_{12}. This suggests the possible presence of unidentified factors in fish solubles.

Baelum (2) reported similar results. The vegetable mixture contained 25 per cent soybean meal and the chickens were kept in batteries:

	Vegetable ration			
	unsupplemented	+ *condensed fish solubles*	+ *APF*	*15 per cent animal protein*
No. of chickens	130	130	130	130
Weight, 8 weeks, g.	580	651	657	718

The two feed supplements increased the weight of the chickens, but the best results were obtained using a feeding mixture containing animal protein. The vegetable rations were not supplemented with methionine.

Corresponding results were obtained in an experiment by Petersen (38):

Group	*1*	*2*	*3*	*4*
Feed	*Basal vegetable*	*Basal + 5 mcg. B_{12} per kg.*	*Basal + 4 per cent fish meal*	*Basal + 4 per cent fish meal + B_{12}*
Weight at 42 days, g.	466	550	600	603
Feed conversion	2·47	2·25	2·18	2·16

Growth was improved by adding vitamin B_{12} to a vegetable ration, but better results were obtained by fish meal.

On the other hand, in 3 market samples of white fish meal, Summers *et al.* (44) found that no unidentified factor could be demonstrated, while fish solubles gave a fairly consistent growth response. These results indicate that fish meals are not reliable sources of unidentified factor activity.

Effect on egg production and hatchability

Cravens, Halpin and McGibbon (15) found no significant differences in egg production between the basal ration fed and the rations containing fish solubles and other supplements. Couch *et al.* (13) using purified rations, state: The results of this study indicate that vitamin B_{12} is required for egg production.

Pensack *et al.* (36) showed that a vegetable diet is deficient in a factor essential for good hatchability. The factor was present in sardine fish meal, and it is transmitted from the hen through the egg to the chick.

In an experiment with laying birds (2) a vegetable diet containing 30 per cent soybean meal was supplemented with condensed fish solubles or APF. For comparison, a laying ration containing animal protein was used:

	Vegetable ration +			
	unsupplemented	*condensed fish solubles*	*+ APF*	*animal protein*
Eggs per hen, 8 months	120	125	130	148
Feed per kg. egg	3·6	3·3	3·2	2·8
Hatchability, per cent	45	74	65	78

Supplementation of the vegetable feed with vitamin B_{12} caused a slightly greater egg yield and better hatching results, but much better results were obtained on using a ration containing animal protein. The vegetable feed was not supplemented with methionine or riboflavin.

Arscott and Combs (1) presented evidence for the presence of an unidentified dietary essential in condensed fish solubles, which is required for normal hatchability of fertile eggs by New Hampshire pullets fed a practical type of ration containing adequate amounts of known nutrient including vitamin B_{12}.

Sullivan, Barnett and Bird (43) found unidentified growth factor activity to be present in a wide variety of fishery by-products. Storage in air at room temperature for 18 months did not alter the growth promoting activity of menhaden meal samples. No evidence was obtained to indicate that the growth factor in fish meals is harmed by excessive drying temperature. It is interesting that Camp, Reid and Couch (10) found that this growth factor is partly associated with the ash of the feedingstuffs in question. This is shown from the following figures:

	Weight 10 weeks g.	*Feed efficiency*
Vegetable basal ration	938	2·92
+ 3 per cent fish solubles	1168	2·70
+ 3 per cent dried whey	1180	2·73
Both	1245	2·75
Ash of		
3 per cent fish solubles	1104	2·86
3 per cent dried whey	1181	2·71
Both	1200	2·70

Although other workers have not reported similar findings, this trial indicates that the micro minerals are important.

The growth promoting effect of fish solubles is neither due to a particularly high biological value nor a content of the essential amino acids deficient in the feed. On the contrary Laksesvela (21) found that fish solubles contain protein of low value. In a trial where chickens were fed a synthetic diet supplemented with fish meal or fish solubles as a source of protein, the following results were obtained:

Percentage of crude protein from				
Herring meal	100	70	25	0
Herring solubles	0	30	75	100
Gain in 3 weeks, g.	61	72	24	20
Survivors out of 21	20	20	13	2

The solubles alone appeared of negligible value as a protein source, but certain mixtures of solubles and meat protein proved superior to meal alone.

When the solubles protein contributed between 15 and 45 per cent of the total protein, the biological value was slightly raised; but a higher proportion of solubles very drastically decreased growth and increased mortality.

On the addition of amino acids to the solubles diet, the growth was considerably improved:

	Gain (g.) after 2 weeks
Herring meal	34 ± 2·9
Herring solubles	7 ± 0·5
Solubles + 10 amino acids	32 ± 2·1

Feed consumption in the solubles group was very low. Supplementation of solubles with 10 amino acids was followed by an increase in food intake of 80–90 per cent. When free amino acids were added to the solubles, only tryptophan improved growth and viability.

Fish silage

Fish silage or fish conservate is used extensively in some countries. The product was first used during the war, when there was a scarcity of proteins, necessitating the use of fish and fish waste unfit for human consumption. Fish silage is manufactured by conserving fish or fish offal in acid at a pH of less than 4. Explicit descriptions of the manufacturing procedures are given by Olsson (33), Petersen (37), Pecht (35), Olsson and Olafsson (34) and Sperling (42).

Høie (20) compared fish conservate with herring meal in the feed for laying birds, and found that the groups fed preserved fish showed just as good egg production and body weight as those fed herring meal.

In feeding chicks with fish meal a slightly better growth was obtained than if a corresponding amount of dry matter of wet preserved fish was used. Any unfavourable influence from feeding wet preserved fish could not be found as to the health and general well-being of the chicks.

The dry-matter content of this product is rather low, the product containing 70–85 per cent water. This results in a high cost of transport, making the product relatively expensive in relation to its nutrition value. It is used to some extent as a supplement to insufficient diets.

A hatchability depressing effect

It will be clear from what has been said above that fish meal, and to some extent other feeds of fish origin, have a nutritive value, with a specific effect due partly to the vitamin B_{12} content, and according to some workers, partly to the content of unidentified factors.

However, certain detrimental characteristics of fish meal and other fish products have been reported. Many workers have thus shown a depressing effect on hatchability with some of the types of fish meal used experimentally.

Black *et al.* (8) observed that the addition of a white fish meal to an all-cereal diet depressed hatchability.

A depression in hatching rates is also observed by Coles (12), using samples of white fish meal obtained from widely separated sources of origin where it was reported that the treatment during manufacture differed. The rations contained 10 per cent fish meal.

Martin *et al.* (29) have reviewed a series of trials where similar results were obtained. His own research showed that the addition of 10 per cent white fish meal to a simple basal ration resulted in a significant depression in hatchability of fertile eggs.

It may be worth while investigating whether or not this depression is connected in any way with the chemicals used for the preservation of the raw material.

Fishy flavour in poultry meat and eggs

Unfortunately fish meal and other fish products have the property of imparting a flavour to poultry meat and to a lesser extent to eggs when fed in large quantities. Great care must therefore be exercised in the use of these products. At the present time much effort is being directed at the manufacture of delipidated fish meal, since the substances which impart the flavour to the meal are primarily found in the fat fraction making fat rich fish meal especially undesirable.

In experiments with chicks Biely *et al.* (7) found that the nutritive value of herring meal was not improved when the oil was removed by extraction with hexane. This was true of commercial flame-dried herring meal and of low-temperature dried meal.

Since the delipidation of fish meal is thought to be technically possible, an increase in the use of fish meal seems very likely in the future.

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METABOLIZABLE ENERGY AND DIGESTIBILITY EVALUATION OF FISH MEAL FOR CHICKENS

by

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The metabolizable energy values and coefficients of digestibility of protein and fat in 6 different samples of fish meal have been determined. Forty-four pens, each with 9 two-week old White Plymouth Rock male chicks, were used. Six pens of chicks were fed a semi-purified ration for a two-week period. Each of 18 other diets, which were formulated by blending the semi-purified ration with the fish meals at 15, 30 or 45 per cent on a dry matter basis, was fed to two pens of chicks.

The dry matter, gross energy, protein and fat contents of the fish meal were determined by chemical analyses. The quantities of excreta energy, fecal nitrogen and fecal fat per unit of diet consumed by the chicks were obtained by analysing the diets and excreta samples. Chromic oxide was used as an indicator; excreta energy was corrected to nitrogen equilibrium; uric acid nitrogen was assumed to constitute 80 per cent of the urinary nitrogen; and urinary fat was assumed to be negligible. The values for the excreta energy, fecal nitrogen (protein) or fecal fat derived from a gram of each fish meal on a dry matter basis were obtained by partitioning the excreta energy, fecal nitrogen or fecal fat per g. of diet consumed to that derived from each fish meal and to that derived from the basal ration by multiple regression techniques. The amounts of metabolizable energy, digestible protein and digestible fat in the fish meals were found by subtracting these values from the respective gross energy, crude protein or fat content of the fish meals on a dry matter basis.

The gross energy values of the 6 samples of fish meal were 5·147, 5·023, 5·021, 4·787, 4·744 and 4·647 calories per g. of dry matter. After subtracting the excreta energy, corrected to nitrogen equilibrium, attributable to the fish meals as found from the feeding experiment, the metabolizable energy of these fish meals was 3·121, 2·807, 2·904, 2·927, 2·897 and 2·469 calories per g., respectively.

The fish meals were found to contain 71·3, 67·4, 70·2, 68·0, 65·5 and 64·6 per cent crude protein on a dry matter basis, and 54·4, 45·4, 52·7, 49·8, 48·2 and 42·2 per cent digestible protein, respectively. The values for the fat content of the fish meals were 11·7, 13·5, 10·6, 10·7, 12·0 and 10·2 per cent and for the digestible fat content of the fish meals, 10·1, 10·2, 8·4, 8·6, 10·2 and 7·6 per cent of the dry matter, respectively.

On the average the fish meals contained 90·4 per cent dry matter; 4·426 gross calories per g., 61·3 per cent protein, 10·4 per cent fat, 2·581 metabolizable calories per g., 44·1 per cent digestible protein, and 8·3 per cent digestible fat. Thus, the gross energy in the fish meals was 58·3 per cent metabolized; and the coefficients of digestibility of the protein and of the fat in the fish meals were 71·8 and 80·2 per cent respectively.

EVALUATION DE L'ENERGIE METABOLISABLE ET DE LA DIGESTIBILITE DE LA FARINE DE POISSON CHEZ LES POULETS

On a précisé les valeurs d'énergie métabolisable et les coefficients de digestibilité des protéines et des graisses pour 6 échantillons différents de farine de poisson. On a utilisé 44 groupes de chacun 9 poulets mâles White Plymouth Rock âgés de deux semaines. Six de ces groupes ont été nourris avec une ration semi-purifiée pendant une période de deux semaines, tandis qu'on donnait aux autres, par deux groupes à la fois, 18 régimes composés par le mélange de la ration semi-purifiée avec des farines de poisson aux taux de 15, 30 ou 45% sur la base de la matière sèche.

La matière sèche, l'énergie globale, la teneur en protéines et en graisses des farines de poissons, ont été déterminées par une série d'analyses chimiques. La quantité d'énergie excrète, l'azote fécal et la graisse fécale par unité du régime consommé par les poulets ont été établis par l'analyse d'échantillons du régime et de l'excrétion.

On a utilisé l'oxyde chromique comme indicateur; l'énergie excrète a été corrigée pour l'équilibre azoté; on a considéré que l'azote urique représentait 80% de l'azote urinaire, et on a considéré comme négligeables les graisses urinaires. Les valeurs pour l'énergie excrète, l'azote fécal (protéines) ou la graisse fécale provenant d'un g. de chaque farine de poisson sur la base de la matière sèche ont été étabiles en répartissant l'énergie excrète, l'azote fécal et la graisse fécale par gramme du régime consommé, entre celles dérivant de chaque farine de poisson et celles dérivant de la ration de base, par des techniques de régression multiple. On a abouti à l'énergie métabolisable, aux protéines digestibles et aux graisses digestibles en défalquant les valeurs précédemment obtenues, respectivement, de l'énergie globale, des protéines brutes et de la teneur en graisse des farines de poisson sur la base de la matière sèche.

Les valeurs d'énergie globale des 6 échantillons de farines de poisson étaient 5,147, 5,023, 5,021, 4,787, 4,744 et 4,647 calories par gramme de matière sèche. Après soustraction de l'énergie excrète, corrigée pour l'équilibre azoté, attribuable aux farines de poisson selon les résultats des expériences d'alimentation, l'énergie métabolisable de ces farines étaient respectivement de 3,121, 2,807, 2,904, 2,927, 2,897 et 2,469 calories par gramme.

On a trouvé que les farines de poisson contenaient respectivement 71,3, 67,4, 70,2, 68,0, 65,5 et 64,6% de protéines brutes sur la base de la matière sèche, et 54,4, 45,4, 52,7, 49,8, 48,2 et 42,2% de protéines digestibles. Les valeurs pour la teneur en graisses de ces farines, étaient respectivement de 11,7, 13,5, 10,6, 10,7, 12,0 et 10,2% et, pour la teneur en graisses digestibles, de 10,1, 10,2, 8,4, 8,6, 10,2 et 7,6% de la matière sèche.

En moyenne, les farines de poisson contenaient 90,4% de matière sèche, 4,426 calories brutes par gramme, 61,3% de protéines, 10,4% de graisses, 2,581 calories métabolisables par gramme, 44,1% de protéines digestibles et 8,3% de graisses digestibles. En conséquence, dans ces farines, l'énergie globale était métabolisée à 58,3%; le coefficient de digestibilité des protéines était de 71,8% et le coefficient de digestibilité des graisses de 80,2%.

EVALUACION DE LA ENERGIA METABOLIZABLE Y DE LA DIGESTIBILIDAD DE LA HARINA DE PESCADO PARA POLLOS

Se han determinado los valores de la energía metabolizable y los coeficientes de digestibilidad de proteínas y grasas de 6 muestras distintas de harina de pescado. Se utilizaron 44 grupos, cada uno de 9 pollos machos de 2 semanas, de la raza White Plymouth Rock. Seis grupos de pollos se alimentaron con una ración semipurificada durante un período de 2 semanas, en tanto que otros 2 grupos se alimentaron a la vez con 18 raciones preparadas mezclando la semipurificada con harinas de pescado a razón de 15, 30 ó 45% sobre la base de la materia seca.

Los contenidos de materia seca, energía global, proteína y grasa de las harinas de pescado se determinaron por una serie de análisis químicos. La cantidad de energía de la excreta y nitrógeno y grasa fecales por unidad de ración consumida por los pollos se obtuvo analizando

muestras de las raciones y excreciones. Se empleó como indicador óxido crómico; la energía de la excreta se corrigió por el equilibrio del nitrógeno; se consideró que el nitrógeno del ácido úrico constituía el 80% del nitrógeno urinario y se supuso que la grasa urinaria era insignificante. Los valores de la energía de la excreta, nitrógeno (proteína) fecal o grasa fecal derivados de un gramo de cada harina de pescado sobre la base de la materia seca, se obtuvieron repartiendo la energía de la excreta, nitrógeno fecal y grasa fecal por gramo de alimento consumido entre los derivados de cada harina de pescado y de la ración básica por técnicas de regresión múltiple. Restando estos valores de las respectivas energía global, proteína bruta o contenido de grasa de las harinas de pescado sobre la base de la materia seca, se averiguaron la energía metabolizable, la proteína digestible y la grasa digestible de la harina de pescado.

Los valores de energía global de las 6 muestras de harina de pescado eran 5,147; 5,023; 5,021; 4,787; 4,744 y 4,647 calorías por gramo de materia seca. Después de substraer la energía de la excreta, corregida por el equilibrio de nitrógeno, atribuible a las harinas de pescado, según se determinó en los experimentos de alimentación, la energía metabolizable de estas harinas fue 3,121; 2,807; 2,904; 2,927; 2,897 y 2,469 calorías por gramo.

Se comprobó que las harinas de pescado contenían 71,3; 67,4; 70,2; 68,0; 65,5 y 64,6% de proteínas brutas sobre la base de la materia seca, y 54,4; 45,4; 52,7; 49,8; 48,2 y 42,2% de proteínas digestibles. Los índices para el contenido de grasa de las harinas de pescado fueron 11,7; 13,5; 10,6; 10,7; 12,0 y 10,2% y para el contenido de grasa digestible de las harinas de pescado, 10,1; 10,2; 8,4; 8,6; 10,2 y 7,6% de la materia seca.

Por término medio, las harinas de pescado contenían 90,4% de materia seca, 4,426 calorías globales por gramo, 61,3% de proteína, 10,4% de grasa, 2,581 calorías metabolizables por gramo, 44,1% de proteínas digestibles y 8,3% de grasa digestible. Por tanto, en estas harinas de pescado la energía bruta se metabolizaba a 58,3%, el coeficiente de digestibilidad de las proteínas era de 71,8% y el coeficiente de digestibilidad de las grasas, de 80,2%.

On the left are two chicks suffering from deficiency in diet while on the right are two normal chicks. Normal chicks were fed a diet in which fish meal was included.

QUALITY OF FISH MEAL IN RELATION TO ITS VALUE AS A SUPPLEMENT TO CORN-SOYBEAN MEAL CHICK DIETS

by

H. M. SCOTT, W. F. DEAN, A. AGUILERA, and R. E. SMITH

Samples of fish meal, domestic and foreign, of known and unknown history, were assayed as the sole sources of protein (10 per cent crude protein) using the technique described by Hinners and Scott (*Poultry Sci.*, **36**, 176–183) with the view of identifying two meals that differed markedly in nutritional quality. The two meals selected for subsequent trials designed to examine supplementary relationships resulted in chick gains of 126 g. (sample "A") and 52 g. (sample "B") for the assay period (14–27 days inclusive).

A corn-soybean meal diet was used as a standard in each of 3 successive trials, where 30, 60 and 100 per cent of the soybean protein was replaced by protein of the superior meal in one series and the inferior meal in a second series with the corn protein remaining constant. In each series the level of protein ranged from 12 to 24 per cent of the diet.

In Trial 1 (30 per cent soya protein replaced by fish meal protein) "A" fish meal was definitely superior to the standard (corn-soya) and to the corn-soya-"B" fish meal diets at all levels of dietary protein in promoting chick growth, while the latter was but slightly better than the standard (corn-soya).

In Trial 2 (60 per cent replacement of soya protein) diets containing sample "A" fish meal, irrespective of protein level, again proved superior to both the standard and the corn-soya-"B" fish meal diets in promoting chick growth. Weight gains on the standard and the corn-soya-"B" fish meal diets were essentially the same at each level of protein.

In the third trial, where 100 per cent of the soya protein was replaced by fish meal protein, the results were essentially the same as in the second trial.

These results demonstrate that supplementing a corn-soya ration with a sample of fish meal known to support excellent chick growth when fed as the sole source of protein, improved the nutritional quality of the diets irrespective of either the amount of soybean meal protein replaced by fish meal protein or the level of dietary protein fed. In contrast, under the same conditions, a sample of fish meal shown to be inferior as a sole source of protein neither detracted from nor improved the nutritional quality of a corn-soya ration. It would appear that the amino acid pattern of corn alone or a combination of corn and soybean meal protein masked the amino acid deficiencies of a sample of fish meal which by itself was incapable of supporting satisfactory chick growth.

QUALITE DE LA FARINE DE POISSON A L'EGARD DE SA VALEUR DE SUPPLEMENTATION POUR LES REGIMES DE MAIS ET SOJA DONNES AUX POULETS

Des échantillons de farines de poisson, d'origine locale ou étrangère, et d'antécédents connus ou inconnus, ont été expérimentés comme sources uniques de protéines (10% de protéines brutes) en utilisant la méthode décrite par Hinners et Scott (*Poultry Sci.*, **36**, 176–183) avec le propos d'identifier deux farines qui différaient nettement en qualité nutritive. Ces deux farines, choisies pour des essais ultérieurs destinés à préciser des relations complémentaires, avaient amené des gains de poids chez les poulets de 126 g. (échantillon A) et 52 g. (échantillon B) dans la période de l'essai (de 14 à 27 jours).

Un régime de maïs et soja a été employé comme base de référence dans chacune de trois expériences succesives où 30, 60 et 100% de protéines de soja ont été remplacés par les protéines de la farine de qualité supérieure dans une première série d'essais, et de qualité inférieure dans l'autre, alors que les protéines de maïs restaient constantes. Dans chaque série, le taux de protéines variait de 12 à 24% du régime.

Dans l'expérience 1, où 30% de protéines de soja étaient remplacées par des protéines de farine de poisson, la farine de poisson A s'est montrée, à tous les taux protéiques essayés et pour promouvoir la croissance des poulets, d'une qualité nettement supérieure à celle du régime de référence maïs-soja et des régimes associant maïs, soja et farine de poisson B; ces derniers apparaissaient cependant légèrement meilleurs que le régime de référence maïs-soja.

Dans l'expérience 2, avec 60% de protéines de soja remplacés, les régimes contenant l'échantillon A de farine de poisson, quel que fût le taux protéique, se sont montrés également supérieurs à la fois au régime de référence et aux régimes associant le maïs, le soja et la farine de poisson B, pour promouvoir la croissance des poulets. Les gains de poids avec le régime de référence et les régimes associant le maïs, le soja et la farine de poisson B, étaient foncièrement identiques à tous les taux protéiques essayés.

Dans la troisième expérience où les protéines de farine de poisson remplaçaient à 100% celles de soja, les résultats étaient foncièrement identiques à ceux de la deuxième expérience.

Ces résultats démontrent que la supplémentation d'une ration au maïs et au soja avec un échantillon de farine de poisson, reconnue pour amener une excellente croissance des poulets, lorsqu'elle est utilisée comme source unique de protéine, améliore la qualité nutritive des régimes, quelle que soit la quantité de protéines de farine de soja remplacée par des protéines de farine de poisson ou quel que soit le taux des protéines fournies dans le régime d'alimentation. En revanche, sous les mêmes conditions d'essai, un échantillon de farine de poisson reconnu de valeur inférieure comme source unique de protéine n'altère pas plus qu'il ne l'améliore la qualité nutritive d'une ration au maïs et au soja. On peut penser que la distribution des amino-acides dans le maïs, seul ou dans une combinaison de protéines de farines de maïs et de soja, masque les déficiences en amino-acides d'un échantillon de farine de poisson qui, utilisé seul, se montrait incapable de soutenir une croissance satisfaisante chez les poulets.

LA CALIDAD DE LA HARINA DE PESCADO CON RELACION A SU VALOR COMO COMPLEMENTO DE LA HARINA DE MAIZ Y SOJA EN LA ALIMENTACION DE POLLOS

Muestras de harina de pescado nacional y extranjera, de antecedentes conocidos y desconocidos, se evaluaron como fuentes únicas de proteína (10% de proteína bruta) empleando la técnica descrita por Hinners y Scott (*Poultry Sci.*, **36**, 176–183), con objeto de identificar dos harinas de calidad nutritiva marcadamente diferente. Las dos harinas seleccionadas para ensayos posteriores proyectados para examinar relaciones complementarias, produjeron en los pollos aumentos de peso de 126 gramos (muestra "A") y 52 gramos (muestra "B") durante el período del ensayo (14 a 27 días inclusive).

Una ración de harina de maíz y soja se empleó como patrón en cada uno de 3 ensatos sucesivos en los que 30, 60 y 100% de la proteína de soja fue reemplazada por la proteína de la harina superior en una serie y de la inferior en otra, con la proteína de maíz permaneciendo constante. En cada serie la concentración de proteína representaba del 12 al 24% de la ración.

En el ensayo 1 (en el que un 30% de proteína de soja fue reemplazado por proteína de harina de pescado), la harina de pescado "A" fue definitivamente superior a la patrón (maíz-soja), y a la de harina de pescado "B" más harina de maíz y soja, en todas las concentraciones de proteína, en la promoción del crecimiento de los pollos, en tanto que la última fue tan sólo ligeramente superior al patrón (maíz-soja).

En el ensayo 2 (substitución de un 60% de la proteína de soja) las raciones que contenían la muestra "A" de harina de pescado, independientemente de la concentración de proteína, también resultaron ser superiores al patrón y a la ración harina de pescado "B" más harina de maíz y soja, en la promoción del crecimiento de pollos. El aumento de peso en las raciones patrón y harina de pescado "B" más maíz y soja fueron esencialmente iguales en todas las concentraciones de proteína.

En el ensayo 3, en el que el 100% de la proteína de soja fue reemplazado por proteína de harina de pescado, los resultados fueron esencialmente iguales que en el ensayo 2.

Estos resultados demuestran que si una ración de maíz y soja se complementa con una muestra de harina de pescado de reconocido valor en la promoción del crecimiento de pollos y cuando se emplea como fuente única de proteínas, la calidad nutritiva de las raciones mejora independientemente de la cantidad de proteína de harina de soja reemplazada por proteína de harina de pescado o la concentración de proteína empleada en la alimentación. Como contraste, y en las mismas condiciones, una muestra de harina de pescado de reconocida inferioridad como fuente única de proteína ni mejora ni perjudica la calidad nutritiva de una ración de maíz y soja. Parece ser que la modalidad de los aminoácidos del maíz solo o de una combinación de proteína de harina de maíz y soja enmascara las deficiencias de aminoácidos de una muestra de harina de pescado que por sí sola es incapaz de mantener constante un crecimiento satisfactorio de los pollos.

Illustrated are two chickens at five weeks of age reared on the same well balanced controlled food under precisely similar conditions. The small bird did not receive any marine fish oil (cod liver oil) but the larger bird did. The level of oil fed was 1 pint to each 112 lb. of food. (*Photo British Cod Liver Oils (Hull and Grimsby) Ltd.*

CONDENSED FISH SOLUBLES IN BROILER NUTRITION

by

J. R. COUCH, A. A. CAMP, and C. R. CREGER

Poultry nutritionists have used three designations to describe the unidentified growth-promoting activity of crude feed ingredients. Fish meal, fish solubles, and meat products have been used to supply the "fish factor". Condensed fish solubles have been found to be a more potent and consistent source of the fish factor than fish meal. The "whey factor" has been reported in dried whey, milk products, corn distillers dried solubles, molasses distillers dried solubles, and dried brewers yeast. The "grass juice" or alfalfa factor is found in the juice of green plants and in dehydrated products produced from such plants. High grade dehydrated alfalfa meal is the practical source of this factor available to the nutritionist. It is realized that such characterizations are quite arbitrary, and that the factors may be one and the same substance when finally isolated and identified.

A seasonal response has been observed to unidentified growth-factors in a number of instances. The present report is concerned with a fairly extensive study which was designed to determine if there were seasonal responses to the whey factor and the fish factor. The study was conducted over a period of one year, during which time six separate experiments were carried out involving 4,800 broiler type male chicks. The basal diet was of the all-vegetable protein type, and was calculated to contain 23·4 per cent protein. The birds were reared on built-up peanut hull litter, were vaccinated for Newcastle and bronchitis, and debeaked at 7 days of age. At the beginning of the sixth week the cockerels were changed to a finisher-type diet, and the protein level was lowered to 20·9 per cent.

Season had a definite effect on the response to unidentified growth-factor activity in the studies which were carried out under the conditions outlined above. If the experiments were started in February and April, the response to condensed fish solubles varied from 25·4 to 26·8 per cent. If the tests were started in June, August, October and January, the percent responses to condensed fish solubles were 8·05, 5·67, 9·98 and 2·22, respectively. The response to dried whey tended to follow the same pattern with the percent growth response for February and April being 21·1 and 19·7. Correspondingly, the responses to dried whey in June, August, October and January were 8·6, 6·0, 4·7 and 1·2. Data from this report do not indicate an additive response when condensed fish solubles and dried whey are added to the basal diet concurrently. Thus it is possible that the samples of dried whey and condensed fish solubles used in this study may have contained the same factor. The response to condensed fish solubles was somewhat greater in the experiments which were initiated in February, April and October. From the data of this series of experiments it can be concluded that there is a seasonal effect in the response to unidentified growth-factor found in condensed fish solubles. Condensed fish solubles and dried whey have a definite growth-promoting effect when added to a broiler diet of the all-vegetable protein type. The response to both supplements added to the diet concurrently was not additive. Thus it would appear, it is not necessary to include more than one of such supplements in a practical broiler diet.

LES SOLUBILISES CONDENSES DE POISSON DANS L'ALIMENTATION DES POULETS A ROTIR

Les nutritionistes spécialisés dans la volaille ont utilisé trois termes pour exprimer les agents non identifiés qui, dans des ingrédients alimentaires bruts, développent la croissance. On a utilisé de la farine brute de poisson, des solubilisés de poisson et des produits carnés pour assurer le "facteur-poisson" (fish factor). Les solubilisés condensés de poisson se sont révélés comme des sources plus efficaces et plus consistantes en "facteur-poisson" que la farine brute de poisson. Le "facteur-petit-lait" a été signalé dans le petit-lait sec, les produits du lait, les solubilisés secs de la distillation du maïs, les solubilisés secs de la distillation des mélasses et la levure sèche de brasserie. Le "jus d'herbe" ou "facteur-luzerne" apparaît dans le jus de plantes vertes et dans les produits déshydratés de ces plantes. Pour le nutritioniste, la source pratique disponible de ce dernier facteur est la farine de luzerne déshydratée de haute qualité. Il est évident que de telles caractérisations sont tout à fait arbitraires, et que ces différents facteurs pourraient se réduire à une seule et même substance quand on aura isolé et identifié les éléments actifs.

On a observé dans un certain nombre de cas une réponse saisonnière aux facteurs de croissance non identifiés. Le présent article concerne une étude assez étendue qui a cherché à déterminer s'il y avait des réponses saisonnières au "facteur-petit-lait" et au "facteur-poisson". Les recherches ont été conduites pendant une année en six expériences séparées mettant en jeu 4.800 poulets à rôtir mâles. Le régime de base était du type à protéines entièrement végétales, et il était calculé pour contenir 23,4% de protéines. Les volatiles étaient élevés sur litière en coques d'arachides; ils avaient été vaccinés pour le Newcastle et la bronchite, et sevrés de becquée à 7 jours. Au commencement de la sixième semaine, les coquelets passaient à un régime de finition et le taux protéique était abaissé à 20,9%.

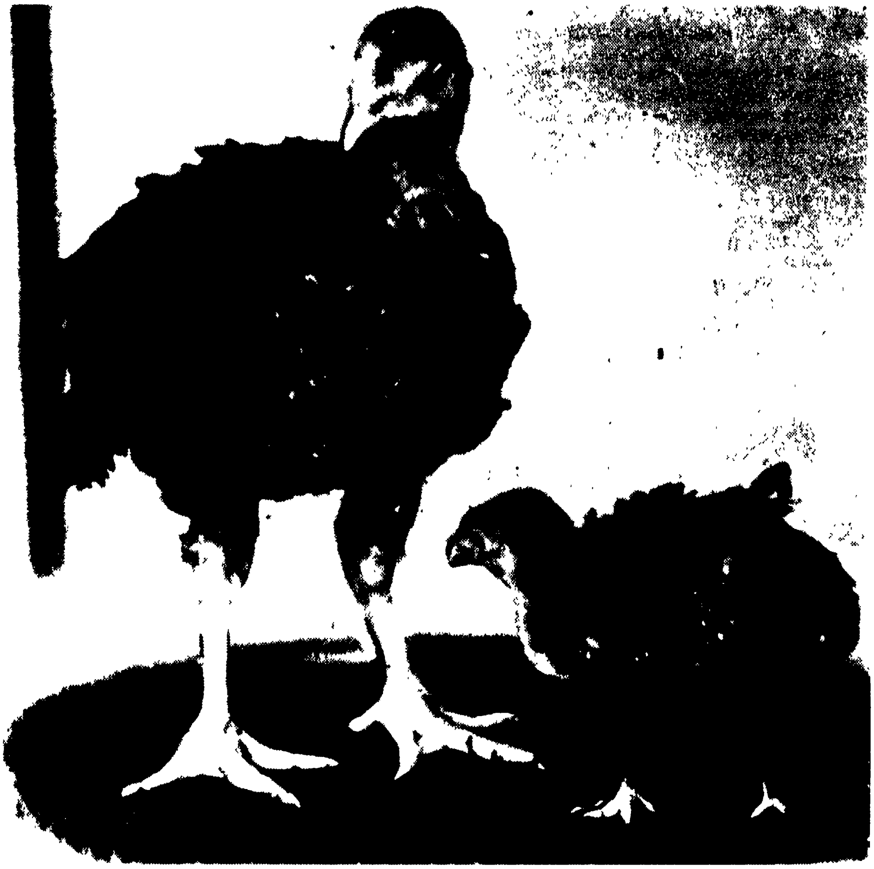
La saison présentait un effet net sur la réponse aux agents de croissance non identifiés dans les études conduites sous les conditions que l'on vient de décrire. Pour les expériences commencées en février et en avril, la réponse aux solubilisés condensés de poisson variait de 25,4 à 26,8%. Pour les expériences commencées en juin, août, octobre et janvier, les réponses en pourcentage aux solubilisés condensés de poisson étaient respectivement de 8,05, 5,67, 9,98 et 2,22. La réponse au petit-lait sec tendait à présenter la même forme avec une réponse de croissance en pourcentage de 21,1 en février et 19,7 en avril, et, corrélativement, de 8,6, 6,0, 4,7 et 1,2 pour juin, août, octobre et janvier. Les données de cet article n'indiquent pas de réponse supplémentaire pour une addition simultanée de solubilisés condensés de poisson et de petit-lait sec au régime de base. Ainsi, il est possible que les échantillons de petit-lait sec et de solubilisés condensés de poisson utilisés dans cette étude aient contenu le même principe actif. La réponse aux solubilisés condensés de poisson était un peu plus grande pour les expériences commencées en février, avril et octobre. D'après les données de ces séries d'expériences, on peut conclure qu'il y a un effet saisonnier dans la réponse au facteur de croissance non identifié qui existe dans les solubilisés condensés de poisson. Les solubilisés condensés de poisson et le petit-lait sec ont un effet net sur l'amélioration de la croissance, quand on les ajoute au régime du type à protéines entièrement végétales dans l'élevage des poulets à rôtir. La réponse aux deux supplémentations concurremment ajoutées au régime n'a pas un caractère additif. Ainsi, il apparaît qu'il est inutile d'inclure dans un régime pratique pour poulets à rôtir plus d'une de ces supplémentations.

LOS SOLUBLES CONDENSADOS DE PESCADO EN LA ALIMENTACION DE POLLOS ASADEROS

Los nutricionistas especializados en la alimentación de aves emplean tres términos para designar los agentes no identificados que promueven la actividad de los ingredientes alimentarios brutos. Se ha empleado harina de pescado, solubles de pescado y productos de la carne para suministrar el "factor pescado". Los solubles condensados de pescado se han revelado como una fuente más potente y consistente del factor pescado que la harina de pescado. El factor "suero lácteo" se ha encontrado en el suero seco, productos lácteos, solubles secos de la destilación del maíz y la melaza y levadura de cervecero seca. El factor "jugo de hierba" o alfalfa se encuentra en el jugo de las plantas verdes y en los productos deshidratados preparados a partir de tales plantas. La harina de alfalfa deshidratada de alta calidad es la fuente práctica de este factor de que dispone el nutricionista. Es evidente que tales denominaciones son completamente arbitrarias, y que los factores pueden ser una y la misma substancia cuando finalmente se aíslen e identifiquen.

Se ha observado en algunos casos una respuesta estacional a los factores de crecimiento no identificados. El presente artículo concierne a un estudio bastante extensivo proyectado para determinar si existen reacciones estacionales el factor suero de leche y al factor pescado. El estudio duró un año, durante el cual se hicieron 6 experimentos separados con 4.800 pollos asaderos machos. El régimen básico era del tipo de proteínas enteramente vegetales y calculado para que contuviera 23,4% de proteínas. Los pollos se habían criado con comprimidos de cáscaras de maní; se vacunaron contra le enfermedad de Newcastle y bronquitas y se les quitaron los picos a los 7 días de edad. Al comienzo de la sexta semana, los gallitos pasaron a un régimen acabador y la concentración de proteína se redujo a 20,9%.

La estación ejerce un gran efecto en la reacción a la actividad del factor de crecimiento no identificado en los estudios realizados en las condiciones descritas anteriormente. Si los experimentos se iniciaban en febrero y abril, la reacción a los solubles de pescado condensados variaba de 25,4 a 26,8%; si comenzaban en junio, agosto, octubre y enero, las reacciones en porcentaje a los solubles condensados de pescado era, respectivamente, de 8,05; 5,67; 9,98 y 2,22. La reacción al suero seco tendía a presentar la misma forma con una reacción de crecimiento de 21,1 y 19,7% en febrero y abril, en tanto que las reacciones correspondientes a suero seco en junio, agosta, octubre y enero eran de 8,6; 6,0; 4,7 y 1,2. Los datos de este informe no indican que hubiera una reacción suplementaria cuando solubles de pescado condensados y suero de leche seco se adicionaban simultáneamente a la dieta básica. Es, pues, posible que las muestras de suero y solubles de pescado condensados empleados en este estudio hayan contenido el mismo factor. Las reacciones a los solubles de pescado condensados eran algo mayores en los experimentos iniciados en febrero, abril y octubre. De los datos de esta serie se deduce que existe un efecto estacional en la reacción al factor de crecimiento no identificado que se encuentra en los solubles de pescado condensados. Tanto éstos como el suero seco mejoran sensiblemente el crecimiento cuando se adicionan a una ración del tipo de proteínas enteramente vegetales en la cría de los pollos asaderos. La reacción a los suplementos añadidos simultáneamente a la ración no era de carácter aditivo, por lo que parece que no es necesario incluir más de uno de tales complementos en una ración práctica para pollos asaderos.



These two turkeys are each five weeks of age. They were hatched, reared and fed identically but the large bird received marine fish oil (cod liver oil) whereas the other did not. (*Photo British Cod Liver Oils* (*Hull and Grimsby*) *Ltd.*

PROTEIN REQUIREMENTS OF BROILERS AS INFLUENCED BY FISH PRODUCTS

by

T. D. RUNNELS and D. G. SNYDER

A broiler feeding experiment has been made using 18, 21 and 24 per cent protein diets. Corn-soy-fat diets supplemented with minerals and vitamins served as the negative controls. The calcium salt of methionine hydroxy analogue, at the rate of 2 lb. per ton, served as the second treatment. Fish meal at a 5 per cent level, and condensed fish solubles at a 2·5 per cent level, served as the third treatment. A combination of Treatments 2 and 3 were used to make up Treatment 4; whilst Treatment 5 was the same as 4 plus the addition of 5 per cent distillers dried solubles and 5 per cent dried cheese whey. All diets were equated for energy, and all treatments were superimposed upon the three protein levels.

Three replicated pens of 10 chicks, consisting of 5 males and 5 females, were fed each diet. The chicks were weighed, and their feed utilization determined, at 4, 7 and 10 weeks of age. (Tables I–V).

A study of the data revealed that body weight of the chicks fed on the corn-soy-fat control diet increased at all weigh periods with each increase in protein level. However, in those diets supplemented with 5 per cent fish meal and 2·5 per cent fish solubles (Treatment 3) the optimum weights (for this experiment) were reached at 21 per cent protein for all weigh periods.

These results are interpreted to mean that the supplementation of the corn-soy-fat diet, with 5 per cent fish meal and 2·5 per cent fish solubles to replace a like amount of soybean protein, resulted in an improved amino acid balance which satisfied the chicks' requirement for protein at a lower level than for those receiving the unsupplemented control diets.

This example is considered of major importance in the efficient utilization of protein in commercial feed formulation.

BESOINS EN PROTEINES DES POULETS, SOUS L'INFLUENCE DES PRODUITS DU POISSON

On a conduit une expérience d'alimentation de poulets à rôtir avec des régimes à 18, 21 et 24% de protéines. Des régimes comportant des huiles de maïs et de soja additionnées de minéraux et de vitamines servaient de contrôles négatifs.

Le sel de calcium d'un dérivé hydroxy de la méthionine au taux de 2 lb. (908 g.) par tonne servait de deuxième traitement. De la farine de poisson à un taux de 5%, et des solubilisés de poisson à un taux de 2,5%, servaient de troisième traitement. Une combinaison des traitements 2 et 3 donnait le traitement n° 4, et le traitement n° 5 reprenait le n° 4 avec une addition de 5% de solubilisés secs de distillation et 5% de petit-lait sec. Tous les régimes étaient énergétiquement identiques et tous les traitements se surimposaient aux trois niveaux protéiques expérimentés.

Trois lots similaires de 10 poulets, comprenant 5 mâles et 5 femelles, ont été alimentés avec chacun de ces régimes. Les poulets ont été pesés, et leur utilisation de la nourriture déterminée, à l'âge de 4, 7 et 10 semaines. (Tableaux I–V).

Une étude des données a montré que le poids du corps des poulets nourris au régime de contrôle comportant des huiles de maïs et de soja s'augmentait à toutes les périodes de pesées pour chaque hausse du niveau protéique. Cependant, dans les régimes supplémentés avec 5% de farine de poisson et 2,5% de solubilisés de poisson (traitement 3), les poids optimum pour cette expérience ont été atteints au niveau protéique de 21% pour toutes les périodes de pesées.

On interprète ces résultats en leur donnant la signification suivante: la supplémentation du régime comportant des huiles de maïs et de soja par 5% de farine de poisson et 2,5% de solubilisés de poissons, pour remplacer un montant identique de protéines de soja, se traduit par une amélioration du bilan des amino-acides qui satisfait le besoin en protéines des poulets à un niveau plus bas que dans le cas des régimes de contrôle non supplémentés.

Cet exemple revêt une importance majeure pour l'utilisation efficace des protéines dans les formules alimentaires commerciales.

NECESIDADES DE PROTEINAS DE POLLOS PARA ASAR Y EFECTO QUE TIENEN EN ELLAS LOS PRODUCTOS PESQUEROS

Se ha realizado un experimento de alimentación de pollos asaderos empleando raciones con 18, 21 y 24% de proteína. Se emplearon como testigos negativos raciones de maíz, soja y grasas con suplementos de minerales y vitaminas. Como segundo tratamiento se empleó la sal de calcio del análogo hidroximetionina a razón de 2 lb. (908 g.) por tonelada. El tercer tratamiento consistió en harina de pescado a la concentración de 5% y solubles de pescado condensados a la de 2,5%. Una combinación de los tratamientos 2 y 3 se empleó como tratamiento 4, en tanto que el tratamiento 5 era igual que el 4 adicionando un 5% de solubles secos de destilería y un 5% de suero de queso seco. Todas las raciones se equipararon en cuanto a energía, y todos los tratamientos se sobrepusieron a las tres concentraciones de proteínas. Con cada ración se alimentó a 3 grupos de 10 pollos formados por 5 machos y 5 hembras. Los pollos se pesaron y el aprovechamiento de la alimentación se determinó a la edad de 4, 7 y 10 semanas. (Tablas I–V).

El estudio de los datos reveló que el peso del cuerpo de los pollos alimentados con la ración testigo de maíz, soja y grasa aumentó en todos los períodos de pesada, con cada incremento en la concentración de proteína. Sin embargo, en las raciones con complemento de 5% de harina de pescado y un 2,5% de solubles de pescado (tratamiento 3), los pesos óptimos para este experimento se obtuvieron con un 21% de proteína para todos los períodos de pesada.

Estos resultados se interpretan en el sentido de que la ración de maíz, soja y grasa, con un complemento de 5% de harina de pescado y 2,5% de solubles de pescado en substitución de una cantidad análoga de proteína de soja, dio por resultado un equilibrio mejor de los aminoácidos que satisfizo las necesidades de los pollos de proteína a concentraciones más bajas que para los que recibían las raciones testigos sin suplemento.

Este ejemplo se considera como de la mayor importancia en el aprovechamiento eficaz de la proteína en la preparación de alimentos industriales.

TABLE I. **(Experiment 1)**

(*Basal Mash*)

	Pounds
Ground yellow corn	83·48
Dehulled soybean oil meal	15·00
Trace minerals	0·16
Sodium chloride	0·56
Premix*	0·80
	100·00

*The Premix supplied the following materials per 100 lb. of basal mash: Vitamin A — 240,000 units, Vitamin D — 80,000 units, Vitamin K (as Heterogen) — 160 mg., Vitamin E — 400 units, Riboflavin — 0·32 g., Calcium Pantothenate — 0·8 g., Niacin — 2·4 g., Choline — 36 g., Vitamin B_{12} — 0·8 mg., Folic acid — 1·5 mg., BHT — 9 g., Terramycin — 0·8 g. (The coccidiostat Amprolium was also added to the diet of the broilers grown in floor pens.) *Note:* This mash was modified as demostrated in Table II, to equate for energy, calcium and phosphorus before being fed.

TABLE II. **(Experiment 1)**

(*Example of Method Used in Equating Diets*)

	Control 16% Protein	*16% Protein + Fish*	*Control 22% Protein*	*22% Protein + Fish*
Basal mash	100·00	100·00	100·00	100·00
Ground yellow corn	35·42	41·30	3·10	9·05
Dehulled soybean oil meal	14·80	2·22	39·80	27·22
Stabilized animal and vegetable fat	3·18	0·50	10·50	7·75
Steamed bone meal	6·60	5·30	6·60	5·30
Menhaden fish meal		7·69		7·69
Condensed fish solubles		2·99		2·99
	160·00	160·00	160·00	160·00

All diets were equated for energy at 1031 calories of productive energy per pound and for protein as specified. All diets were fortified to supply adequate levels of vitamins and minerals.

TABLE III. **(Experiment 1)**

(*Summary of Data*)

White Rock Cockerel Chicks 8 Weeks of Age

	Average Body Weights		*Feed Utilization*	
Per cent Protein	*Corn-soy Control Diets*	*+ 5% Fish Meal + 2·5% Fish Solubles*	*Corn-soy Control Diets*	*+ 5% Fish Meal + 2·5% Fish Solubles*
16	2·59	3·06	2·44	2·24
18	3·03	3·24	2·16	2·19
20	3·25	3·32	2·11	2·17
22	3·30	3·60	2·09	2·01

Note: These diets were equated to supply 1031 calories of productive energy per pound. The chicks were grown in battery brooders and each treatment was replicated twice.

TABLE IV. **(Experiment 2)**

(*Summary of Data*)

White Rock Cockerel Chicks 8 Weeks of Age

	Average Body Weights		*Feed Utilization*	
Per cent Protein	*Corn-soy Control Diets*	*+ 5% Fish Meal + 2·5% Fish Solubles*	*Corn-soy Control Diets*	*+ 5% Fish Meal + 2·5% Fish Solubles*
22	2·58	3·04	2·34	2·29
26	2·78	3·01	2·32	2·17

Note: These diets were equated to supply 1050 calories of productive energy per pound. The chicks were grown in floor pens.

TABLE V. **(Experiment 3)**

(*Summary of Data*)

Equal Sexes of Vantress Cross Broiler Chicks 10 weeks of age

	Average Body Weights		*Feed Utilization*	
Per cent Protein	*Corn-soy Control Diets*	*+ 5% Fish Meal + 2·5% Fish Solubles*	*Corn-soy Control Diets*	*+ 5% Fish Meal + 2·5% Fish Solubles*
18	3·44	3·64	2·75	2·65
21	3·63	3·98	2·67	2·54
24	3·98	3·92	2·54	2·43

Note: These diets were equated to supply 1007 calories of productive energy per pound. The chicks were grown in battery brooders and each treatment was replicated 3 times.

DISCUSSION

On the paper submitted by Dr. Baelum, **DR. R. BRAEKKAN** (Norway) observed: Vitamin B_{12} occurs in fish and fish products as hydroxycobalamin, while fermentation products may contain several analogs. Experiments on liver storage have shown that rats and chicks absorb Vitamin B_{12} from fish equal to microbiologically determined values. Salmonella in fish meal seems a serious problem in some countries; however, it should not be forgotten that salmonella has been reported present also in vegetable meal products.

DR. NGO BA THANH (Viet-Nam): In Viet-Nam shrimp flour is used in our poultry-feeding work. Enormous quantities of very small shrimp, almost plankton size, are found on the coast. They are dried easily in the sun, and were at first used for fertilizer. This dried product was tested in poultry feeding last year, and its nutritive value was shown to be comparable to that of fish meal. Fewer salmonella are found in shrimp flour than in fish meal. The hens fed on shrimp produced less odorous eggs than those fed on fish meal.

DR. H. R. BIRD (U.S.A.): Do you know the protein content?

DR. NGO BA THANH (Viet-Nam): There were no data on composition at hand; probably, the protein content was about 5–10 per cent lower than that of fish meal.

DR. M. A. RAAFAT (U.A.R.): Shrimp meal is produced in Egypt, and the protein content is about 40–42 per cent. It is not air dried, but is prepared in the usual way. It has a high mineral content. Similar results were obtained in poultry feeding as with fish meal.

DR. H. L. A. TARR (Canada): Shrimp meal has a less objectionable flavour; Miss Watts of Florida found no flavour and no TBA from shrimp meal.

DR. J. A. LOVERN (U.K.): In reply to Dr. Tarr's question concerning the nature of the fat oxidation process in shrimp meal, it is perhaps significant that much of the fat in crustaceans consists of wax esters rather than triglycerides.

DR. K. AMANO (Japan): The crude protein content of shrimp meal is 32·4 per cent. If the shrimp are boiled in water, however, the protein content may be lower.

DR. K. J. CARPENTER (U.K.): Feed mixers want a high-energy value and low fiber, such as are supplied, for example, by soybean meal. In the United Kingdom high-fat herring meals are more desirable. If technical problems could be overcome, and if fat could be returned to fish meal, then a product of high caloric value would be available and used.

DR. L. E. OUSTERHOUT (U.S.A.): Some varieties of fish in the United States contain types of fat that do not give flavour problems. Some meal manufacturers do not press out the oil. Consequently, many New England meals may contain 15–18 per cent oil and produce high energy values.

DR. A. M. LEROY (France): It is preferable not to have too fatty meals. Although they may be rich in energy, fat may harm the vitamin content. Furthermore, the oils rich in saturated fats are not so desirable. Thus, the preference for pork fat to suet.

DR. R. BRAUDE (U.K.): There is a divergence of views between pig growers and broiler growers. High-energy fish meal is not wanted for pig feeding, while high-fat meal is preferred for broilers.

On the papers submitted by Dr. Potter and his colleagues, **DR. G. VARELA** (Spain) asked: (1) With what degree of precision were the coefficients of digestiblity of proteins in broilers determined, and how significant are the uric acid excretion data? (2) How exact are the data on digestible protein of fish meals?

Dr. L. M. Potter (U.S.A.): Because urine and feces are voided together by chickens, it is difficult to differentiate between digestible and non-digestible nitrogen. Two methods are available for this determination: (1) By means of surgery, the urine and feces can be obtained separately; but this method is laborious. (2) About 80 per cent of the digested nitrogen is in the form of uric acid (Katayama—Japan; O'Dell—United States in *Poultry Science*). However, I believe 70–75 per cent is a more realistic figure. By determining the uric acid in the excreta, the two different forms of nitrogen can be estimated.

On the paper submitted by Dr. Couch, **Dr. H. Fougere** (Canada) remarked: Seasonal changes in fish solubles have been demonstrated. Could the differences in responses shown by Dr. Couch's experiments have been due to these? During certain seasons, cod and haddock are particularly susceptible to "bilginess", an anaerobic form of spoilage. Such spoilage can be demonstrated in the laboratory by placing fish in ice between boards from a fish hold. The odour materializes when spoilage occurs, or in some cases within 2 days. There is a seasonal colour change in the protein of cod and haddock; it is white in the spring, but becomes progressively more yellow as the season advances. Would this help to explain other seasonal changes? What were the sources of the fish products used by Prof. Couch?

Dr. J. R. Couch (U.S.A.): The solubles came from the West Coast; the origin of the fish meal is not known. The same sample of fish solubles was used throughout the year. The variations in results were due to season, to genetic differences in chicks, and to other causes. The chicks were purchased on the open market.

Dr. A. M. Leroy (France): The seasonal differences demonstrated by Prof. Couch are most impressive. Could appetite (as indicated by speed of ingestion of feed) have been related to these differences? Appetite has a bearing on energy intake.

Dr. J. R. Couch (U.S.A.): While seasonal differences in appetites do exist, we observed no relationship between appetite and the seasonal differences.

Dr. H. M. Scott (U.S.A.): We can detect differences as great as those observed by Couch from week to week in the same strain of birds; but when this happens, it is time to depopulate, clean up, and start over again.

Dr. G. Borgström (U.S.A.): In reference to Dr. Murayama's Table I, samples 4 and 5 show more than 20 per cent of the dry matter unaccounted for. Can it be assumed that such dry matter was chitin or was some other ingredient responsible?

Dr. H. M. Scott (U.S.A.): I do not wish anyone to leave this conference feeling that fish meal is (in general) inferior in nutritive value. There are differences between types or brands of fish meals. I do not know what we were measuring besides protein quality and amino acid balance. Perhaps, it was an unidentified growth factor. It is my impression that fish meal "G" was inferior because of amino acid deficiencies. Additional measurements would be required to determine whether amino acids were the limiting factors. We cannot assume a lysine deficiency. Dr. Ousterhout's work shows that arginine is most subject to destruction during processing. In this case, chicks are the most useful experimental animals; rats do not clearly indicate arginine deficiency, but chicks do.

The production of broilers on the grand scale shown here is possible only by the provision of adequate protein (to which end fish meal is important), and the provision of the best of conditions.—*Farmer and Stockbreeder photograph.*

FISH AND FISHERY PRODUCTS IN RATIONS FOR FUR-BEARING ANIMALS

by

PHILIP J. SCHAIBLE

Substantial amounts of fish and fishery products have been used for many years in mink foods. In general, performance of mink has been good when these products have been fed with due caution as to their quality and composition. However, mink-industry journals have occasionally published articles giving detailed accounts of adverse effects from feeding certain species of fish, particularly at high levels. On the other hand, there are many reports from ranchers who have fed fishery products for years with great success. Variability in composition (and consequently in nutritive value) due to species of fish, seasonality of the catch, and proper handling, distribution and cold storage, has apparently been responsible for the differences in feeding results obtained.

Certain species of fish are superior to others in their effect on growth, fur-development and reproduction. The possibility of utilizing fishery products which are procurable in large amounts, but which are not being used at present to the maximum extent, is explored. Further research is needed to establish the bases upon which greater use of these fish can be achieved.

LE POISSON ET LES PRODUITS DE LA PECHE DANS LES RATIONS POUR LES ANIMAUX A FOURRURE

Depuis plusieurs années, on a utilisé des quantités appréciables de poisson et de produits de la pêche dans l'alimentation des visons. En général, les résultats obtenus ont été satisfaisants quand on a tenu sérieusement compte de la qualité et de la composition de ces produits. Cependant les revues de l'industrie du vison ont parfois publié des articles contenant des comptes rendus détaillés sur les effets contraires obtenus quand les visons avaient été nourris avec certaines espèces de poissons et, en particulier, d'une façon intensive. D'autre part, il existe de nombreux rapports d'éleveurs de visons qui leur ont donné des produits de la pêche pendant des années et avec grand succès. Les variations de composition (et par conséquent de la valeur nutritive) selon les espèces de poisson, les différentes saisons de pêche et les conditions particulières de manipulation, de distribution et d'entreposage sous froid sont probablement responsables des résultats divergents de cette alimentation.

Certaines espèces de poissons sont supérieures à d'autres quant à leur effet sur la croissance, sur le développement de la fourrure et sur la reproduction. On étudie ici la possibilité d'utiliser des produits de la pêche disponibles en grandes quantités mais qui, actuellement, ne sont pas utilisés au maximum. Des recherches ultérieures sont nécessaires pour établir les bases d'une utilisation plus importante de ces poissons.

EL PESCADO Y LOS PRODUCTOS PESQUEROS EN LA ALIMENTACION DE ANIMALES DE PELETERIA

Importantes cantidades de pescado y productos pesqueros se emplean desde hace muchos años en la alimentación de los visones. En general, los visones han reaccionado satisfactoriamente cuando se les han suministrado estos productos, tomando precauciones en cuanto a su calidad y composición. Sin embargo, las publicaciones de la industria peletera han contenido algunos artículos exponiendo detalladamente los efectos perjudiciales que ha tenido el suministro de ciertas especies de pescado, particularmente en cantidades importantes. Por otro lado, hay muchas noticias de criadores que emplean productos pesqueros desde hace años con plena satisfacción. La variación en la composición, y por tanto en el valor nutritivo, debido a la especie del pescado, momento de la captura, y manipulación, distribución y almacenamiento en frigoríficos adecuados, parecen haber sido los causantes de las diferencias de los resultados de la alimentación obtenidos.

Hay especies de pescado que tienen mejor efecto que otras en el desarrollo, crecimiento del pelo y reproducción. Se estudia la posibilidad de emplear productos pesqueros fáciles de obtener en grandes catidades, pero que actualmente no se aprovechan hasta el máximo. Se necesitan investigaciones ulteriores para determinar la manera de utilizar con más amplitud este pescado.

FUR farming of fish-eating animals is confined at present to mink. The marten, fisher, weasel, otter, wolverine, ferret and badger are difficult to raise in captivity, though they are available in abundance in the wild. Fox farming was important a few decades ago, but it has been largely superseded by mink ranching. Chinchillas and rabbits are grown for fur under domestic conditions, but they are not primarily fish-eaters.

Large litters, rapid growth of young, satisfactory food conversion and efficient breeding performance are the bases for profitable fur production. For all of these, optimum nutrition is a prerequisite. Important advances have been made in fur animal nutrition in recent years; but there is still a paucity of basic nutritional information. Estimates of nutrient requirements, effects of nutritional deficiencies and composition of foods for fox and mink, are discussed in a National Research Council report (34).

Geography largely determines the species and levels of fish used for feeding mink. The Scandinavian countries, Japan, Canada and the United States all have long coast lines, and as a result mink rations contain a high proportion of marine fish and fishery products. In these areas, it is quite common to feed 50 per cent of fishery products; sometimes as high as 70 per cent. Inland, fresh-water fish are used for 25 per cent of the ration—not as high as along the coast, because there is competition here from by-products of the meat-packing industry. The world over, fish and fishery products make up a very substantial part of commercial mink food. Even in the wild, mink consume much fish—about a third of their natural diet.

Kinds of fish fed

North American mink ranchers use many varieties of fish (33). From the Atlantic Ocean come whiting (*Merluccius bilinearis*), cod (*Gadus morrhua*), haddock (*Melanogrammus aeglefinus*) and rosefish (*Sebastes marinus*). The Pacific Ocean supplies turbot (*Atheresthes stomias*), red and black rockfish (*Sebastodes ruberrimus* and *melanops*), petrale sole (*Eopsetta jordani*), English sole (*Parophrys vetula*), Dover sole (*Microstomus pacificus*), rex sole (*Glyptocephalus zachirus*), sand sole (*Psettichthys melanostictus*), sand dab (*Citharichthys sordidus*), rosefish (*Sebastodes alutus*), and Pacific hake (*Merluccius productus*). Inland lakes and streams in Canada and the United States contribute fresh-water smelt (*Osmerus mordax*), Lake Superior herring (*Leucichthys artedi*), sheepshead (*Aplodinotus grunniens*), carp (*Cyprinus carpio*), Lake Michigan chub (*Leucichthys artedi*), whitefish (*Coregonus clupeaformis*), pike (*Stizostedion vitreum glaucum* and *Esox lucius*), yellow perch (*Perca flavescens*), burbot (*Lota lota maculosa*), ciscoes (*Leucichthys* spp.), black bullhead (*Ameiurus melas*), sucker (*Catostomus commersonnii*) and alewife (*Pomolobus pseudoharengus*).

From the waters surrounding the Scandinavian countries, the fish most used in mink feeding are cod (*Gadus callarias*), haddock (*Gadus aeglefinus*), whiting (*Gadus merlangus*), coalfish (*Gadus virens*), herring (*Clupea harengus*), mackerel (*Scomber scrombrus*), stone biter (*Anarrhichas lupus*), lumpfish (*Cyclopterus lumpus*) and flounder (*Pleuronectes platessa*). The fish used mainly in Japan for mink feed is the flatfish (*Pleuronectidae*).

Fish and fishery products are, in general, held in high esteem by mink ranchers. Nevertheless, a review of the literature shows that, whilst they are frequently praised for mink food, they are sometimes condemned. A few articles in mink journals report that feeding fish, particularly at high levels, is dangerous (9). Yet, other reports show that even higher levels of fish can be fed without harm (36). Many articles compare performances of mink on fish and on meat diets. Sometimes, these reports assume and imply that "fish" is an ingredient of constant composition and uniform quality.

Variability in composition of fish and fishery products

Fish and fishery products differ in nutritive value owing to many factors: species, seasonal nature of the catch, maturity, size, sexual maturity, nature of the available food, etc. (44). Some species of fish are high in water or fat content, others low. At times, fish may contain roe. Some are cannibalistic, others are vegetarian in their feeding habits. Thin and small fish are chilled more rapidly than large and round fish; thus, they have less chance for spoilage.

Fish and fishery products are marketed in many forms—whole fish, filleted fish with or without viscera, fish heads, etc. These and many other factors illustrate why fish and fishery products vary in composition and, consequently, food value. Frequently, there are greater differences between batches of fish of the same species than there are between species. This explains why some ranchers may get good results, and others poor results, from feeding "fish" to mink. The nature of the fish products has an important bearing on the performance obtained from its feeding to mink. And this must be specified if the mink rancher is to make best use of fishery products. Analysis of some fish and fishery products commonly used in mink rations are given elsewhere by the writer (46).

The mink industry

A few statements concerning mink production may be helpful, in order to indicate the nature of the food supplies needed by the mink industry. Mink are carnivorous animals. They are grown in the northern part of the Northern Hemisphere, or in areas of high altitude, where there is a cool climate and accessible low-cost food supplies. In the Great Lakes area, there is an abundance of fresh-water fish and meat by-products from the meat packing industry. In this area, fish competes with meat for a place in the mink ration.

Commercial mink are derived from stock originally obtained from Alaska (United States) and Nova Scotia (Canada). The former were of large size with coarse fur; the latter were small, but of fine fur texture. Progeny of these matings are now distributed all over the world.

Mink have certain peculiarities with respect to growth, reproduction and fur development—and these affect feeding practices. Mink have one breeding season a year. They mate in March, and ovulation is induced by the mating act (23). There is delayed implantation of the ova. Females whelp from 38 to 76 days after mating. About twice as many eggs are shed as develop into kits. Growth of kits is very rapid—from 9 g. at birth to 30 g. at 1 week, and 105 g. at 3 weeks of age. A large litter of kits may weigh as much as their mother in 3·5 weeks—entirely from her milk. About this time kits start to eat some solid food. Mink kits weigh 300 g. at 6 weeks. By 16 weeks of age, kits have 80 per cent of their final body weight, and over 95 per cent of their body length and skeletal growth (45).

Mink are housed in separate cages, and are thus entirely dependent on the food provided. They cannot forage to supplement their diet. All the nutrients necessary for body and skeletal growth, fur growth, reproduction, gestation and lactation must be provided in the food. For that reason, and because mink have a very short digestive tract and a very rapid rate of food passage, mink foods must be palatable, quickly digestible and nutritionally well balanced. To nourish the animals during the different phases of their lives, the fish, meat and cereal portions of the diet are varied from time to time. Mink foods and mink feeding practices related to stage of life and season have been discussed elsewhere by the writer (46).

Fish and fishery products marketed for mink food

The principal animal food fed to mink in early fur-farming was horsemeat. When supplies became short, fur farmers turned more and more to fish and fishery products. They were confronted with a confusing array of products. They found that some fish were available "in the round", while others were eviscerated. Fishery products were marketed as racks (carcasses which remain after filleting) with or without viscera. Frozen products came both raw and cooked. Waste from fish cutting and canning operations, as well as mixed surplus and rough fish, were available for mink feeding.

Since then dried, condensed, and homogenized fish products have also found their way into mink foods—as a basis for reconstituting fish or as a mink cereal supplement. Some of these products are dried fish meal, dried fish solubles, and their combination, fish flour (31), condensed fish solubles, homogenized fish and glandular hydrolysate. In addition, there are fish liver, fish oils and other specialty products. A discussion of all these products is beyond the scope of this article; suffice to say, they all have known feeding values when properly used in conjunction with other food ingredients. All of these products have a place in the utilization of fish and fishery products for feeding fur-bearing animals.

The treatment of fish, from the time of catch to the time that mink consume the product, is extremely important. This can make the difference between a high quality and a poor product. Perhaps most failures where fish have been involved can be traced to careless treatment during the periods of processing, distributing and storage. In general, fish should be chilled with ice at sea, and sharp frozen when boats arrive in port (which they should do frequently). Antioxidants are sometimes added during processing, particularly in the case of fish flour or fish meal. Sometimes phosphoric acid is added to ground fish, which is then canned. Drying temperatures should not be excessive. Antibiotics have been used with fresh fish to keep down bacterial spoilage. Since fish and fishery products are highly nutritious, they tend to spoil more rapidly than nutritionally poorer media. Consequently, extra care must be exercised in handling and feeding these ingredients.

Although whales (Balaenopterids) are mammals, they are usually discussed with fish with regard to their use in mink foods. Whalemeat is a by-product of oil production. It is a lean red flesh, marketed to mink ranchers as a replacement for horsemeat and fish (39, 52).

Nutritional values of fishery products for fur bearers

The ability of fishery products to satisfy the nutritional needs of mink in terms of energy, protein, fat, vitamins and minerals is related to their composition (2). However, cooking, canning, drying and other types of preparation affect the available nutrient values.

Fish and fishery products are considered by mink food manufacturers and ranchers primarily as a protein food (12). They rate fish equivalent to meat in this regard. Substantial levels of meat and fish always result in rations high in protein. In fact, practical mink rations contain protein considerably in excess of the mink's requirement for this nutrient. To illustrate, 70 per cent of fish and meat and 30 per cent of cereal in the ration would provide 35 per cent of protein on a dry matter basis. This exceeds by far the highest protein requirement (22 per cent, dry basis) for growth of mink as established by the National Research Council (34). Supplementing the cereals with high protein ingredients, therefore, does not give beneficial effects if used in high fish and meat diets (18).

Proteins from other sources, however, do not perform as well as fresh fish and meat, even though they have equivalent amino acid composition. Certainly, amino acid balance is as critical in mink foods as in livestock feeds in general. It would appear, therefore, that fresh fish and meat are more than donors of protein. Fish is known to be a valuable source of fats, vitamins and minerals as well. Research has shown, however, that even these additional nutrients do not offset the difference in performance between the natural and synthesized product. Enzymatic content and better palatability of the fresh products may be involved but so far researchers have not pinpointed the critical factors.

Recent research (35) with the chick has shown that fish meals and, therefore, fresh fish are excellent sources of essential amino acids. There is much less variability in quality than occurred in the past. Steam and vacuum-dried meals are superior to those produced by improperly operated hot air driers. Protein quality, as measured by digestible, critical amino acids, is good in today's meals. There is little difference in amino acid composition of the protein from meals prepared from various species of fish, whole fish, cannery waste, fresh or spoiled fish. The greatest loss in digestibility of the protein and oil occurs during the "cure" of the meal when it may become overheated due to oxidation of the oil. Turning the meal frequently avoids this problem.

Mink digest fats efficiently but do not do as well with protein (32); ocean whiting has a protein digestibility of 87 per cent compared with 92 per cent for boneless horsemeat and 89 per cent for chicken entrails. In contrast, the digestibilities of fats are: fish oil 97 per cent, lard 96 per cent, and tallow 92 per cent.

The fat level in the mink ration is adjusted by varying the levels of the cereal and the low and high fat ingredients. Ranch rations usually have less than 22 per cent fat but there is evidence that higher levels can be used effectively if the fat is stabilized (47).

The vitamin requirements of mink are not too well established as indicated in the National Research Council bulletin (34). Practically, however, mink feeds contain ingredients such as fish, meat and brewer's yeast which are excellent reservoirs of vitamins (8, 21).

Fish and fishery products from marine and fresh-water sources have been compared and found to be about equivalent (3, 6, 43). Fish has also been compared with animal products such as horsemeat, tripe, chicken and turkey waste with excellent results (7, 15, 16). Different types of fish have also been checked for their value for growth, furring and reproduction of mink (1, 30, 50).

To use fish products properly in mink rations they must be balanced by other ingredients. For example, whiting and hake are quite low in fat content. Consequently, other ingredients should be selected to offset this. High fat foods, even lard or other fat itself, can be used to bring up the fat content to proper levels.

Another form of ration balance is one born of experience. Mink ranchers, who have fed fish products with more or less success, have found that the amount of any one kind of fish product to feed should be limited to 15 per cent. This makes for variety of ingredients which complement each other. Further, it limits any untested ingredient to a rather low level. Difficulties do not seem to happen with this type of feeding, because it provides a suitable margin of safety.

Mink food has to be acceptable from the standpoint, not only of growth and reproduction, but just as importantly for its value in the production of fur. Some fish are known to promote a good rate of growth, others good fur. For example, red and black rock fish are salt-water fish that have been found to be superior for furring. On the other hand, turbot is excellent for growth, but not for furring. Through research and experience mink ranchers have found which type and how much of the various fish products can be fed safely and profitably.

Nutritional difficulties related to feeding fish to mink

"Cotton" mink are extremely anemic and have a grey-white, flimsy underfur which causes the pelt to be practically worthless. This condition has been widespread but sporadic, usually associated with feeding large amounts of raw whiting and hake in North America, and coalfish in Norway. Researchers (1, 17) have shown that eviscerated whiting does not have the objectionable factor; eviscerated hake has it to some extent, raw viscera of both species has it to a great extent.

Rancid and oxidized fats do not cause "cotton" pelts. Feeding multiple B_1 vitamins, copper, lysine and tyrosine are without effect. The objectionable factor can be destroyed by thorough cooking. Intramuscular injections of organic compounds containing iron, such as iron-dextran, prevent the "cotton" condition with its accompanying anemia. Consequently, the objectionable factor is a heat-labile antimetabolite which interferes with iron metabolism.

Certain strains and families, as well as individual mink, differ in susceptibility to this condition. Consequently, some ranches have less trouble from this problem than others. To prevent "cotton" pelts, avoid the objectionable fishes or reduce amounts fed to levels that can be tolerated. If raw whiting is used, have it eviscerated: or use whiting and hake products that have been cooked. With the new knowledge concerning the nature of the nutritional problem, the incidence of "cotton" mink should be reduced substantially in the years ahead.

"Yellow-fat" disease, or steatitis, is caused by feeding fish or fishery products that have become rancid. It usually affects young mink kits—they refuse feed one day, and are often dead the next. At necropsy, the subcutaneous fat is pigmented yellow-brown and the spleen enlarged and blotched. The polyunsaturated nature of the fatty acids of fish fats is responsible for development of the condition in association with rations deficient in vitamin E. Antioxidant treatment of the fish product and vitamin E supplementation of the mink diet help prevent steatitis. Ocean herring and mackerel as well as fresh-water chubs and alewives are particularly inclined toward the development of this condition if they are stored too long.

Rancidity of fishery products develops from too long and improper cold storage. Fish must be processed and frozen rapidly to produce a quality product (11). Hold material no more than 3 months in cold storage, on a "first in-first out" basis to minimize the problem of rancidity. Freezing does not improve the product; if it started to spoil before freezing, it will still have detrimental effects. Antioxidants are being used increasingly to treat fish meal, flour and oil, to help prevent deterioration of the fat (29). Tests with high levels of antioxidants have shown them to be harmless to mink during the growing period (38).

Chastek paralysis in fox and mink is a thiamine (vitamin B_1) deficiency caused by the enzyme, thiaminase, which destroys this vitamin in the ranch ration prior to and during ingestion (14). This enzyme is found in a number of species of fresh and salt-water fishes (10). Smelt, carp, burbot, bullhead, sucker, alewife and ocean herring contain thiaminase. It is particularly concentrated in the viscera. Nonthiaminase fish may at times contain this enzyme in the viscera, if they have consumed thiaminase fish as prey.

To overcome this problem, cook such fish at 180°F for 15 minutes to destroy the heat-labile thiaminase enzyme. Those who cook their cereal can do both at the same time. However, thiaminase fish can be fed raw on alternate days with nonthiaminase fish. Fed in this manner, fox and mink are able to obtain sufficient thiamine for their well-being.

Urinari calculi, nursing sickness, pregnancy disease, wet belly, fatty change of liver and gastroenteritis are not thoroughly understood but are considered nutritional in nature (13). Fish and fishery products have not been specifically associated with any of these problems; but the fact that these products comprise a substantial part of most practical mink rations makes the rancher question them when he is in trouble. For example, some mink rations have been noted to be too high in mineral content. Fish products contain liberal amounts of mineral. The particular problem then is not concerned so much with fish as it is with controlling and balancing mineral contents.

Fish in dry diets for mink

Commercial mink food are composed primarily of fresh or frozen products. Naturally, attempts have been made to develop mink rations of readily available, easily stored dry ingredients such as are fed to poultry and other domestic animals. These dry diets usually contain high levels of fish meal (24, 25, 26).

Best results with dry diets have been obtained during late growth of kits and maintenance of adult animals of both sexes. Unsatisfactory results have been obtained during gestation and, particularly, lactation. The quality of fish meal appears to be critical: vacuum-dried fish meal with solubles is best. Higher fat levels improved the rate of growth of kits. Breeding performance was as satisfactory on dry diets as on ranch-type rations.

Dry diets use lower-cost ingredients which are in ample supply and more stable in price than fresh fish products. They store without refrigeration and there is less likelihood of spoilage and food-borne infections. While only partially successful until now, there is reason to believe that greater use will be made of this type of feeding in the future (37).

Trends for the future

Fish and fishery products filled the vacuum left when horsemeat no longer became available in sufficient quantity. Meat by-product supplies are fairly constant year to year; so if the mink population increases in the future, fishery products will be expected to provide this necessary part of the ration.

Several sources of fish have not, as yet, been exploited for mink feeding. The menhaden (*Brevoortia tyrannus*) abounds in the Atlantic Ocean and Gulf of Mexico, from New England to Texas. Practically all is now reduced to oil and fish meal, the latter for use in poultry and swine feeds (27, 28). The menhaden has not been used for feeding mink, because it is an oily fish and ranchers have feared "yellow fat" disease. Recent pilot studies (49), however, indicate that 60 per cent of the meat portion of the diet can be menhaden, if thiamine is added to prevent Chastek paralysis. Cooked menhaden, and the cooked press cake remaining after extraction of the oil, are also satisfactory and more practical as a substitute for animal products. The press cake seems especially promising for mink feeding.

The alewife and other rough fish have become so abundant in the Great Lakes that they are a menace to commercial fishing. Recent preliminary experiments (38a, 46) have demonstrated that mink can be fed satisfactorily on alewives if these are processed under normal meat-canning conditions. The use of better fishing gear (20) has shown that these fish can be harvested profitably for mink food.

Frozen fish in blocks and packages require considerable time for thawing—and during this time quality deteriorates. Recently, equipment for rapid thawing has entered the human food field (4) and may well be suitable for thawing fish for mink. This should reduce the risk of spoilage of mink food, prior to feeding and when on the feeding boards.

More efficient equipment has been developed for freeze-drying (5). This should produce superior dry fish flour and meals that might replace more of the fresh product in mink foods.

Greater use is likely to be made of dry cereal for mink feeding in the years ahead. This will reduce the amount of fresh fish needed, but will demand more high quality fish meal. Certain fermented cereal products contain unidentified growth factors frequently supplied by fishery products (48). Much ocean fish is trucked from the coasts to inland points. These products have very high amounts of water which adds considerably to the cost of transport, and yet is available locally. Dry, concentrated or condensed fish products thus would lower the cost of mink foods, if they could be used satisfactorily.

The recent trend of collaboration between mink ranchers, university research nutritionists, and biologists of the United States Fish and Wildlife Service, augurs well for the solution of many of the troublesome problems that at present stand in the way of maximizing the use of fish and fishery products for mink feeding. This cooperation keeps the mink rancher informed about the availability and values of certain fishery products, and at the same time advises the fishing industry of the foods and feeding needs of the mink industry. It will help speed up solutions to some of the vexing problems involved in the use of fish and fishery products for feeding fur-bearing animals.

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THE UTILIZATION OF MENHADEN PRODUCTS BY MINK

by

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In preliminary studies it was demonstrated that fresh, whole menhaden included in the diets of adult or growing mink at a level of 40 per cent would result in a thiamine deficiency. Supplementation with 0·5 mg. of thiamine hydrochloride per mink per day prevented the symptoms from appearing, and promoted normal weight gains. Therapeutic doses of 50 mg. promptly alleviated all symptoms. It may thus be concluded that fresh whole menhaden contains an active thiaminase. Successive experiments showed that menhaden press cake (cooked whole menhaden minus most of the fat) did not contain this antienzyme. Studies were then initiated to examine the usefulness of whole menhaden press cake as a replacement for horsemeat in mink diets. Sufficient tallow was included with the menhaden to make it equal in gross energy to the components it replaced. Experiments with 10 growing kits per group resulted in final live weights at pelting respectively for the following diets of: (1) Ranch diet control, 4·1 lb.; (2) Press cake replacing the horsemeat, 4·04 lb. A subsequent experiment compared the following diets utilizing 36 weaning male kits per group: (1) Ranch diet control including 20 per cent horsemeat, (2) Diet (1) with horsemeat replaced by press cake and fat, (3) Diet (1) with horsemeat replaced by press cake, saturated with a fish peptide solution and fat, (4) Diet (1) with horsemeat replaced by an enzymatically digested whole menhaden plus fat. All fish products were prepared by Marine Chemurgics Inc., Morehead City, N.C. The following data were collected for each group; gain 6–16 weeks, gain 6–29 weeks, gain in body length to pelting and pelt score (better pelts have lower scores). The results were respectively for each group: (1) 1041 g., 1540 g., 8·3 in., 6·2; (2) 1064 g., 1526 g., 8·6 in., 7·1; (3) 1036 g., 1510 g., 8·5 in., 7·3; (4) 1035 g., 1468 g., 8·3 in., 7·1. None of the differences between diets were statistically significant. Preliminary results using diets (1) and (2) suggest that diet (1) results in superior reproduction as indicated by live kits at 42 days. The above studies suggest a useful place for whole menhaden press cake in mink diets.

UTILISATION DES PRODUITS DU MENHADEN DANS L'ALIMENTATION DU VISON

Au cours d'études préliminaires, il a été démontré que l'inclusion de 40% de menhaden frais entier dans le régime alimentaire du vison adulte ou en pleine croissance entraînerait une carence en thiamine. L'adjonction de 0,5 mg. de chlorhydrate de thiamine dans la ration journalière de chaque animal évite l'apparition des symptômes et permet un accroissement normal du poids. Une dose thérapeutique de 50 mg. fait rapidement disparaître les symptômes. On peut en conclure que le menhaden frais entier contient une thiaminase active. Des expériences ont montré que les gâteaux de presse de menhaden (cuits entiers et dégraissés) ne contiennent pas cet anti-enzyme. Des études furent ensuite entreprises pour déterminer l'utilité de ces tourteaux de menhaden entier comme succédanés de la viande de cheval dans le régime alimentaire du vison. Une quantité suffisante de suif fut ajoutée au menhaden afin d'égaler en pouvoir énergétique les éléments qu'il remplaçait. Des expériences poursuivies avec des groupes de visons comprenant dix petits chacun ont permis d'obtenir les résultats ci-après, avec les régimes alimentaires indiqués, en ce qui concerne le poids vif constaté au moment du dépouillement: (1) Alimentation-type de ferme, 4,1 lb. (2) Tourteaux remplaçant la viande de cheval, 4,04 lb. Une expérience ultérieure consista à comparer les résultats obtenus grâce aux régimes alimentaires suivants, avec des groupes comprenant chacun 36 mâles sevrés: (1) Alimentation-type de ferme, comprenant 20% de viande de cheval; (2) Régime (1) avec des tourteaux et des matières grasses en remplacement de la viande de cheval; (3) Régime (1) dans lequel la viande de cheval était remplacée par des tourteaux saturés d'une solution de peptide de poisson et des matières grasses; (4) Régime (1) dans lequel la viande de cheval était remplacée par du menhaden entier qui avait subi une digestion enzymatique et par des matières grasses. Tous ces produits du poisson étaient préparés par "Marine Chemurgics Inc.", Morehead City, Caroline du Nord. Les données ci-après furent recueillies pour chaque groupe: augmentation de poids de 6 à 16 semaines, augmentation de poids de 6 à 29 semaines, accroissement de la longueur du corps jusqu'au moment du dépouillement et calibre de la fourrure (les meilleures peaux ont le plus faible calibre). Les résultats relatifs à chaque groupe furent respectivement les suivants: (1) 1041 g., 1540 g., 8,3 inches, 6,2; (2) 1064 g., 1526 g., 8,6 inches, 7,1; (3) 1036 g., 1510 g., 8,5 inches, 7,3; (4) 1035 g., 1468 g., 8,3 inches, 7,1. Aucune des différences constatées à la suite de ces divers régimes n'était significative du point de vue statistique. Les résultats préliminaires obtenus avec les régimes (1) et (2) laissent supposer que le régime (1) produit une reproduction supérieure comme indiquée par des petits vivants à 42 jours. Les études ci-dessus semblent faire ressortir l'utilité des tourteaux de menhaden entier dans l'alimentation du vison.

LA UTILIZACION DE LOS DERIVADOS DEL SÁBALO EN LA DIETA DEL VISON

Estudios preliminares han demostrado que la inclusión de un 40% de sábalo entero fresco en la alimentación de visones adultos o en crecimiento, produce una deficiencia de tiamina. La adición de 0,5 mg. de hidrocloruro de tiamina en la ración diaria de cada animal, evitó la aparición de los sintomas y facilitó el crecimiento normal. Dosis terapeúticas de 50 mg. hicieron desaparecer rápidamente todos los síntomas. Se deduce que el sábalo entero fresco contiene una tiaminasa activa. Experimentos posteriores demostraron que la torta prensada de sábalo (cocido entero y desgrasado casi por completo) no contiene este antienzima. A continuación se iniciaron experiencias para determinar el valor de la torta de prensa del sábalo entero como substituto de la carne de caballo en la alimentación de visones. Se adicionó al sábalo sebo suficiente para igualarlo en energía total a los compuestos substituidos. Experimentos subsiguientes con grupos de 10 visones en crecimiento dieron los siguientes pesos en vivo en el momento de despellejarlos: (1) con la alimentación normal testigo: 4,1 lb.; (2) con torta de prensa en vez de carne de caballo, 4,04 lb. Posteriormente se emplearon grupos de 36 visones macho recién destetados para comparar las raciones siguientes: (1) ración normal testigo, mas un 20% de carne de caballo; (2) ración (1), pero substituyendo la carne de caballo por torta de prensa y grasa; (3) ración (1) con la carne de caballo substituida por torta de prensa saturada con una solución de péptidos de pescado y grasa; (4) ración (1) con la carne de caballo substituida por sábalo entero digerido enzimaticamente mas grasa. Todos los productos de pescado fueron preparados por Marine Chemurgics Inc., Morehead City, North Carolina. De cada grupo se obtuvo la siguiente información: aumento desde las 6 hasta las 16 semanas, aumento desde las 6 hasta las 29 semanas, aumento en la longitud del cuerpo hasta el momento de despellejar y graduación de pieles (las mejores pieles tienen las graduaciones más bajas). Los resultados fueron respectivamente para cada grupo: (1) 1041 g., 1540 g., 8,3 pulgadas, 6,2; (2) 1064 g., 1526 g., 8,6 pulgadas, 7,1; (3) 1036 g., 1510 g., 8,5 pulgadas, 7,3; (4) 1035 g., 1468 g., 8,3 pulgadas, 7,1. Ninguna de las diferencias fué significativa desde el punto de vista estadístico. Los resultados preliminares, usando las raciones (1) y (2), sugieren que la (1) da por resultado una reproducción superior según lo indican los pequeños visones vivos a los 42 días. Los estudios anteriores sugieren un papel útil de las tortas prensadas de sábalo entero en las raciones de visones.

DISCUSSION

On the paper submitted by Dr. Schaible, **Dr. G. Borgström** (U.S.A.) remarked: A few facts on thiaminase in fish might be put on record. Thiaminase was first discovered in clams, later in fresh-water fish, and finally, in salt-water fish. It is not specific to any one of these groups. The Japanese "ayn" lacks this enzyme. Reports seem to indicate that the herring of European waters lack thiaminase, while those taken on the North American coast frequently contain this enzyme. This points to the feed (plankton or invertebrates) as the source of this enzyme. Indian studies have found thiaminase distributed among different fresh-water fish; also among brackish and salt-water fish. They report three separate thiaminases: one specific to fresh-water fish, and two encountered chiefly in brackish-water and salt-water fish. These latter two can be distinguished by the pH optima (3·5 against 5·6). Amines are potent activators of thiaminase. A Japanese scientist, Kimure, discovered fish bacteria capable of producing thiaminase. This brings up the point whether thiaminase is intrinsic to the fish or has an exogenous origin, even though it may occur in the muscle. But liver, kidneys, viscera, and gills are most potent. Livers of some fish may contribute 20 or 30 times more than the muscle. These statements have been brought out to underline how little we know on this very important point. This problem, undoubtedly, may have implications in the use of fish as human food. I also want to remind you that this phenomenon is not unique to fish. Bracken poisoning of cattle is one of many phenomena which has brought up the possibility that thiamin might be destroyed by agents other than enzymes.

Dr. H. R. Bird (U.S.A.): What is the moisture content of the press cake referred to in Dr. Warner's paper?

Dr. S. A. Miller (U.S.A.): The presscake was produced by the wet-reduction method to contain approximately 50 per cent moisture. In the glazed press cake, the moisture content was higher, since clarified stickwater (to eliminate the phosphatides) was added.

Dr. H. R. Bird (U.S.A.): What progress has been made on dried feeds (containing fish meal) similar to poultry mash feed?

Dr. P. J. Schaible (U.S.A.): Using much dry feeds, we have had the best success during the late growth and maintenance of mink. Gestation and particularly lactation are problems, however. Other people have not had as much success with this diet as we have had. This may be due to the better quality of the vacuum-dried meal we were using. Dried foods have proved as good as fresh foods for pelt quality. Dry foods may be superior for maintenance. One should be able to supply about one-half the diet for mink through dried foods. Dry foods are sometimes fed in a wet mash form. In other words, water is added to the dry foods prior to feeding.

Dr. H. L. A. Tarr (Canada): For chicks, we have found that solubilized fish (from acid or enzyme digested fish) are of lower nutritive value than meals prepared by conventional processes.

Mr. M. Stansby (U.S.A.): Do you have any information on the oil content of the press cake, and the possible occurrence of steatitis?

Dr. S. A. Miller (U.S.A.): North Carolina summer menhaden, containing 8–9 per cent fat, yielded a scrap of about 9 per cent fat. The final press cake had about 5·5 per cent fat. No problem was encountered with yellow-fat disease. The fish was frozen at sea with carbon dioxide, and held frozen under nitrogen until used.

Dr. P. J. Schaible (U.S.A.): A bulletin which describes mink production, including a chapter on the use of fish, is available upon request. Borgström's comments relating to thiaminase were appreciated. In reply to Dr. Tarr, these meals included the solubles.

Dr. A. Bacigalupo (Peru): Has selenium or antioxidants been used for mink foods beyond that work on Vitamin E reported here?

Dr. P. J. Schaible (U.S.A.): There is no specific information on record of a relationship of steatitis to selenium; most work was conducted before the recent interest in selenium. Recent work by Lookley has shown that the incidence of steatitis is reduced by antioxidants.

Dr. F. J. King (U.S.A.): Are the mink feeds formulated by a producer or by the ranchers?

Dr. P. J. Schaible (U.S.A.): In the beginning, the ranchers did both the formulating and mixing. Later, cooperatives stepped in to mix and distribute fresh and frozen foodstuffs. Currently, mink food manufacturers produce complete diets, and also cereal premixes which can be (and often are) supplemented.

Dr. V. E. Newe (U.S.A.): Is wet belly disease of nutritional origin?

Dr. P. J. Schaible (U.S.A.): Some people think so; we do not. Nutrition may be an influencing factor, however. This problem in the live animal is caused by the dribbling of urine on the fur. This may cause some deterioration of the pelts. Wet belly in the pelts is what the furrier sees. These spots on the leather side of the skins are believed to be due to late maturation of hides—indicating immaturity.

At the end of this Discussion, **Prof. H. Caballero** (Chile) asked leave to submit the following recommendations:

(1) To promote research with a view to determining the true nutritive value of fish meals and their derivatives for animal consumption (especially for monogastric animals), setting up, in connection with these evaluations, practical methods that can lead to the establishment of well-defined standards useful to the manufacturer as well as the expert and the farmer.

(2) To promote research with a view to producing information as to the effective use of fish and its derivatives (fish meal, by-products, waste, etc.) in animal nutrition.

This will permit efficient utilization of these products in animal nutrition, and bring about considerable economy in various protein products of animal origin which will thus reach the consuming public directly.

(3) To study the use in animal nutrition of those products or sub-products of low nutritive and commercial value that, properly supplemented with fish meal or its derivatives, could be converted into foods of considerable nutritive value.

PART V

DEMAND FOR FISH AS HUMAN FOOD AND POSSIBILITIES FOR INCREASED CONSUMPTION

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THE DEMAND FOR FISH AS HUMAN FOOD

by

R. HAMLISCH and R. A. TAYLOR

Principal trends in the demand for fish as human food in Western Europe, in North America, and in developing countries, are summarized.

Available evidence suggests that average consumption levels in Western Europe and North America are not likely to change materially in the foreseeable future. The outlook is favourable for selected products in the "luxury" class characterized by high income elasticities. Consumption of less valued fish, on the other hand, may substantially decline with improvement in levels of real income.

Greater emphasis on quick-freezing and advances in the fields of technology, transport, storage, and distribution can be expected to widen markets for fishery products, especially in some European countries. Demand may also be stimulated by introduction of new products, by careful attention to price policies and trade practices, and by intensified promotional activities.

Competition from other animal protein foods will, if anything, increase rather than diminish. In order not to lose their markets, therefore, the fishery industries of developed countries will have to maintain considerable flexibility in their policies, and see to it that relative costs are not allowed to get out of line.

Competition from other foods is much less important in developing countries. There is no question that fish consumption could be greatly expanded in most of these countries, provided:

(1) increased supplies were made available in markets not adequately served, because of lack of facilities for transport and marketing, and because of various institutional factors limiting market quantities;

(2) educational campaigns were initiated to increase the knowledge of nutritional aspects and to break down superstitions and taboos;

(3) incomes were raised to enable consumers to enrich their diets by the addition of animal protein foods, particularly fish, the cheapest source of such foods.

LA DEMANDE EN POISSON COMME ALIMENT HUMAIN

L'article résume les tendances principales de la demande en poisson comme aliment humain dans l'Europe occidentale, l'Amérique du Nord et les pays en voie de développement.

Les données disponibles laissent penser que les niveaux moyens de la consommation en Europe occidentale et en Amérique du Nord ne se préparent pas, probablement, à changer matériellement dans un avenir prévisible. La perspective est favorable en ce qui concerne les produits de choix destinés à la classe supérieure caractérisée par de hautes disponibilités financières. La consommation du poisson de moindre valeur, par ailleurs, peut diminuer d'une façon notable par l'amélioration du revenu moyen.

On peut s'attendre à un plus grand effort dans la congélation rapide et à des progrès dans les champs de la technologie, du transport, de l'entreposage et de la distribution qui élargiront le marché du poisson, surtout dans quelques pays européens. La demande peut être aussi stimulée par l'introduction de nouveaux produits, par une attention soignée portée à la politique des prix et aux usages commerciaux et par des activités dynamiques en promotion de ventes.

Quoi qu'il en soit, la concurrence des autres aliments protéiques animaux augmentera plutôt qu'elle ne diminuera. Afin de ne pas perdre leurs marchés, les industries poissonnières des pays développés devront en conséquence maintenir une souplesse considérable dans leur politique et veiller à ce que les prix de revient relatifs ne s'écartent pas de la direction prévue.

La concurrence des autres produits alimentaires est bien moins importante dans les pays en cours de développement. Il est hors de doute que la consommation du poisson pourra s'étendre largement dans la plupart de ces pays, à la condition:

(1) que des approvisionnements accrus soient disponibles sur les marchés, qui ne sont pas encore correctement servis, par suite d'un manque de facilités de transport et de commercialisation et par suite de l'existence de facteurs institutionnels divers qui limitent les quantités mises sur le marché;

(2) que des campagnes éducatives soient entreprises pour accroître la connaissance en matière de nutrition et pour briser des superstitions et tabous;

(3) que les revenus soient augmentés pour permettre aux consommateurs d'enrichir leur régime par l'addition d'aliments protéiques animaux, particulièrement de poisson, le moins cher d'entre eux.

LA DEMANDA DE PESCADO COMO ALIMENTO HUMANO

El artículo resume las tendencias principales de la demanda de pescado como alimento humano en Europa occidental, Norteamérica y países en desarrollo.

Los datos disponibles hacen pensar que los niveles medios de consumo en Europa occidental y en Norteamérica no es probable que cambien sensiblemente en un futuro previsible. Las perspectivas son favorables para productos seleccionados destinados a la clase superior, caracterizada por fuertes disponibilidades financieras. Por otro lado, el consumo de pescado de menor valor puede disminuir sensiblemente con la mejora de los ingresos reales.

Puede esperarse un mayor esfuerzo en la congelación rapida y adelantos en tecnología, transporte, almacenamiento y distribución para ampliar los mercados de productos pesqueros, especialmente en algunos países europeos. La demanda también puede ser estimulada por la introducción de nuevos productos, atención cuidadosa a las políticas de precios y prácticas comerciales, y acelerando la promoción de ventas.

Sería normal que la competencia de otros alimentos de proteínas animales aumentara en vez de disminuir. Por tanto, para no perder sus mercados, las industrias pesqueras de los países desarrollados tendrán que mantener muy flexibles sus políticas y ocuparse de que los costes relativos no se aparten de las líneas previstas.

La concurrencia de otros alimentos es mucho menos importante en los países en desarrollo. No hay duda alguna de que el consumo de pescado podría ampliarse mucho en casi todos ellos a condición:

(1) de que aumentara el suministro en mercados insuficientemente servidos, debido a falta de medios de transporte y comercialización y a la existencia de factores institucionales diversos que limitan las cantidades a ellos enviadas;

(2) que se inicien campañas educativas encaminadas a incrementar los conocimientos de los aspectos nutritivos y a romper supersticiones y tabús;

(3) que se eleven los ingresos para que los consumidores puedan enriquecer su alimentación mediante la adición de alimentos con proteína animal, particularmente el pescado, que es el más barato de todos.

PART I. THE BASIS OF ENQUIRY

IN the opinion of a noted agricultural economist there is much confusion about the economic effects of advances in the young science of nutrition:

"Better nutrition is a good thing" he writes, "but under what conditions and at what price? All too frequently the goal of better nutrition is approached in altogether too narrow a physical-biological framework with no clear conception of the possibility (costs), or of the preference, and how they are related one to the other" (1).

In line with this thinking, this paper has been prepared to broaden the basis of the discussion of the place of "fish in nutrition".

It is interesting to reflect on how different our daily lives would be, if man's behaviour as a consumer was motivated purely by objective factors. Domestic animals, to make a comparison, are fed on diets which aim to provide maximum feeding content at minimum cost; and the prices of animal feeds tend to vary directly with the richness of the particular factor—protein or other nutrient—for which they are purchased. Looked at in this way, the preference system which man applies to his own consumption appears quite irrational. In Great Britain in 1958, for example, consumers obtained 25 per cent of their protein from meat which absorbed 28 per cent of their total expenditure on food; they obtained 4 per cent from cheese which took up 2 per cent of their expenditure on food and they obtained 1 per cent from fat fish (2) at a cost equal to 0·2 per cent of their total food expenditure (3).

These three foodstuffs give other nutrients besides protein, but they are known chiefly for their protein content. Yet it can be seen that expenditure on each varied inversely with the cost per unit of protein. If man applied the same rules in feeding himself as in feeding his domestic animals, food consumption patterns would, one suspects, look very different. Herring, which at current prices is an extremely cheap source of protein, would no doubt be consumed in much larger quantities in most European countries, and less would be destined for the fish meal works.

Lack of knowledge about the nutritive value of fish relative to other foodstuffs has a lot to do with this behaviour. But of course, many subjective factors revealed in the tastes, likes and dislikes, and habits of consumers play a large part in determining people's preferences.

The objectives of the analysis of demand

Scope and method of demand-analysis vary with the objectives of the enquiry. Results have a meaning, therefore, only in relation to the particular aim for which a study has been undertaken. In assessing the place of fish in human diets, for instance, utilization of catches for industrial and animal feeding purposes is not taken into account. Nor is it necessary, when computing per capita consumption figures for a country, to distinguish between supplies produced domestically and supplies imported from abroad. If the focus of interest, however, is on the economic implications of the demand for fish, the procedure has to be reversed: total net income, both from food and non-food fisheries, has to be calculated, and a clear distinction has to be made between the economic contributions, in relative terms, of production and of foreign trade. Fish may be of growing dietary importance in a particular country; yet the mere diagnosis of such a trend, if not supplemented by economic evidence, does not warrant any conclusions with respect to the future outlook of the fishery industries or the economy in general.

Most demand studies aim at more than just describing what elements account for past trends. In increasing measure, they provide the means for charting the future course of markets. For forecasting purposes, it is not enough to know the determinants of demand and their relative significance. Projections must be concerned also with the constancy of the various determinants, and the likely effects of changes in these factors.

Nutritional and economic data are only a part of the information that is needed for the formulation of public policy. In addition to the place of fish in human diets and to the economic implications of consumption patterns, the government has to consider conservation, and sociological and technological aspects.

The determinants of demand

In the widest sense, the demand for one commodity is related to the demand for all others, because a relative change in the quantity demanded (and the expenditure) will affect what is available for the other commodities. Consequently, all factors influencing the demand for one commodity, must have an influence on the demand for all others. Clearly, however, amongst the relationships between one commodity and other commodities or other factors, some are more direct and have more practical significance than others.

The first task, therefore, is to reduce the list of possible determinants to a much shorter list of probably significant ones. This is where common sense and a certain amount of economic theory are used. The next stage is the collection and analysis of facts to test the hypotheses made; the presumption being that without taking all possible influences into account—particularly those difficult to measure—one can arrive at a measure of the relationships between certain factors and the commodity in question. This quantitative analysis of economic problems, or econometrics, has developed rapidly over recent years. Considering the number and scope of the questions requiring an answer, however, only a beginning has been made in this field. Moreover, while such studies and the whole approach is inherently historical, in that the data used relate to past periods, the practical value of this method of analysis must lie in the greater understanding that it gives of current and future developments, which is contingent upon the stability through time of the relationships established. A sound knowledge of the stability of the functions cannot be obtained, however, until a larger body of data, covering longer periods of time, has been accumulated. Those who seek answers today, therefore, must put up with much more tentative replies.

The kind of relationships calculated to date cover the more obvious basic determinants of demand: the relationship between the demand for A and the price of A, the demand for A and the prices of substitute and complementary commodities, B, C, D, etc.; the demand for A and income per capita, and expenditure on A and income per capita. In the case of foodstuffs, the relationships between demand, income and the sizes of households and their composition are also frequently calculated.

There are, however, many other determinants which are much more difficult to quantify. In the case of fish, these include such factors as: the uncertainty of supply and uncertainty of quality; instability of prices; institutional factors, such as the availability of facilities for distribution; consumer tastes and habits; and the extremely important one—sales promotion in all its forms. From a policy standpoint, the latter determinants may sometimes be more important than the readily quantifiable determinants, because they can more easily be changed.

In the long run, population growth is probably the most important single determinant of the total demand for food and the total demand for fish. Also of special significance from the standpoint of effective demand in the long run is the degree to which supply can be expanded in response to rising requirements without seriously (by a change in relative price ratios) affecting the relationship of fish to competitive commodities.

In recent years, motivational research has found increasing application in the study of the process of decision-making in some developed countries and can be expected to become an important tool in demand analysis in the future. In our present state of knowledge, however, its application is very limited. Today, time series on population, catches, trade, prices, incomes, etc., and the results of household and institutional consumer surveys are the principal sources of data for demand studies.

The data used are in physical terms (catches, edible weight consumed, etc.) or in monetary terms (dollar expenditures, income, etc.). They may be global, national, or regional totals. They may relate to specific groups of products or of people (fresh fish, households, income classes of consumers, etc.) or to individuals (per capita consumption or expenditures). They may relate to periods of specified length (annual retention, weekly expenditures, etc.), all depending on the objective and method of enquiry.

The rôle of fish in human diets

There is a wide variation in the level of consumption of fishery products as well as in their relative importance in the human diet in different parts of the globe. In the top ranks of consumers (where per capita retention—in terms of catch weight—is in excess of 45 pounds a year) are a few Far Eastern countries, the United Kingdom, Portugal, and most of the Scandinavian countries. In a sizeable number of countries, consumers use, on the average, anywhere from 45 pounds to one-half this amount. However, many countries, including some of the largest and most populous in the world, consume even less fish. There are even entire regions, such as the Near East, where virtually no fish is eaten.

Per capita data do not tell the whole story. The level of consumption may be the same in two countries; yet in one of them fish may be of substantially greater relative importance in the diet than in the other.

To give an example: in the Soviet Union, fish accounts for more than 10 per cent of animal protein consumption; but in the United States, where per capita consumption of fish is at a similar level, the corresponding percentage is only about a third as large.

In considering the place of fisheries in the economies of the two countries, we must also remember that imports constitute only 3 per cent of supplies retained in the Soviet Union as against one-third of supplies in the United States. In the Soviet Union, a very substantial expansion in per capita consumption of fish is foreseen by 1965, while no significant change is anticipated in the United States. Basic government policy in the Soviet Union is said to actually favour development of fisheries over other sectors of the food economy, particularly livestock production (4).

On a regional basis, the relative importance of fish in human diets is greatest in the Far East. There it accounts for almost one-fifth of the entire animal protein intake. This region includes Japan, where animal protein consumption is relatively high, chiefly the result of a pronounced preference for fish. In other countries in the region, animal protein intake is much lower. Fish, however, make up a significant proportion of this intake.

Elsewhere in the world, fish plays a less important part in enriching the animal protein content of diets. Of the European countries, Iceland is the one that most closely resembles Japan in its heavy reliance on fish protein. In most other countries, even those with a relatively high per capita consumption, fish constitutes only a modest part of total protein intake. In the Near East, in Africa, and in the Americas, fish consumption is low not only in absolute terms, but also in relation to total amount of animal protein consumed.

Beyond citing a few statistical aggregates, there is little opportunity for generalizing on the demand for fish on a world-wide basis. Consumption varies greatly within even very small areas. While some patterns may be determined by geographic and natural conditions, such as climate and closeness and richness of fishable waters, others are related primarily to social, cultural, and religious characteristics, and to economic and technological factors.

An exhaustive discussion of the demand for fish as human food the world over could very well be the subject of a separate meeting. The observations in this paper will be limited, therefore, to the description of basic trends in selected regions. The discussion will be in three sections: one devoted to Western Europe, one to North America, and one to the developing countries.

PART II. THE DEMAND FOR FISH IN WESTERN EUROPE

A recent OEEC publication summed up the trend in fish consumption in Europe by stating that in "... the OEEC area as a whole, the increase in supplies has roughly been in step with the post-war population growth" (5). The report however, also explains, that there have been a number of diverse elements within this aggregate. In the high income countries like Belgium, Denmark, Germany, Holland and the United Kingdom, fish consumption per capita declined, while it increased in such countries as Austria, France, Ireland, Italy, Portugal, Spain and Turkey.

It should perhaps be pointed out that in some of the latter group of countries consumption is rising from a rather low base, relative to the European average. This is true, for example, of Austria, Ireland, Italy and Turkey. But it is certainly not so in the case of Portugal, where consumption is relatively high, nor of Spain, where it is also above the European average. Similarly, amongst those countries showing declining fish consumption per capita, in some the level is above the European average, while in others it is below.

Appendix 1 shows the level of fish consumption per capita in various European countries and illustrates the changes that have taken place between 1948 and 1958 and since 1938. Due to the aftermath of war, the figures for 1948 are not necessarily representative of free market consumption levels. Average consumption per capita in Europe has remained at approximately 15·5–16·0 kg. per annum, but, as can be seen, the variations around this average are very considerable.

Geographic factors influencing demand

The concept of a market demand implies a market area within which this demand exists. If the preference of the inhabitants of a definable area are appreciably different from those in another area, or if the distribution systems in one area differ from those in another to such an extent that effective demand is appreciably affected, then it is of little practical value to consider these two areas as forming one market.

Information is most readily available on a country-by-country basis. But market areas for fish are not always most clearly defined by national boundaries. Nor do between-country differences in European per capita consumption levels truly reflect the relative preferences for fish. Rather different geographical breakdowns would be needed to distinguish the different markets for various kinds of fish and fish products in Europe (6).

For example, statistics show that Italy is the principal European market for stockfish. But most stockfish are sold in Venice and the surrounding districts, and in Sicily and Naples (7). There also tend to be two separate markets for salted cod; one in the industrial north for the heavily salted fish; the other in the agricultural south for the lightly salted hard dried fish (8). Similar differences are to be found in other countries (9).

The OEEC study, referred to earlier, pointed out that generally "fish consumption in coastal areas is several times higher than that in inland areas, particularly in continental Europe; thus in France annual fish consumption in many inland areas is below 1 kilo per inhabitant (the national average was 11·9 kilos product weight in 1958) and it is estimated that one third of the French population never eat fish. In Germany some years ago, fish consumption in a northern coastal area was found to be 33 kilos per head as against 4 kilos in an inland district. In the Mediterranean countries, particularly Turkey, such differences are often pronounced" (10). Many people might consider that these illustrations themselves show very pronounced differences. Equally striking differences are to be found in other countries.

Co-existent with such regional differences are differences between urban and rural areas. A survey in the Federal Republic of Germany revealed that in places with less than 500 inhabitants, consumption per capita (in the mid-1950's) was 8·11 kg., whereas in places with more than 100,000 inhabitants it was 14·28 kg. (11).

Such differences come about, at least in part, because of quality factors. In cities, the quality of fresh and lightly-cured fish is better, and prices are lower. In the more thinly populated country districts, distribution difficulties mean poorer quality and higher costs.

Originally, the lack of a quick means of transport prevented distribution from the fishing ports to inland areas. Railway development and the ubiquitous internal combustion engine have greatly diminished this problem. Wide differences between consumption levels still exist; these differences are due more to the lack of distribution outlets for fish in rural and semi-rural areas.

The demand for different products

The various basic concepts developed by economists to reduce the analysis of demand to a logical discipline are in their pure forms valid only on certain rather theoretical conditions. One of these, important in the present context, is that the supply of the commodity in question be homogeneous. It is patently obvious that this assumption is not satisfied in the case of fish. Fish is a convenient generic term, but covers a range of commodities and products which are as heterogeneous to the economist as they are to the biologist. To the economist this heterogeneity is seen not only in the variety of species but also in the form of processing and in the freshness, size, and other factors which determine the quality of the product to the consumer. The characteristics of demand can differ very considerably from one product-group to another.

The make-up of fish consumption has been changing in many European countries. In general, there has been a decline in the demand for salted and dried products and for cheaper fresh fish in the northern European countries. Meanwhile, the demand for better quality fresh and cured fish and the more expensive processed fish has increased. In Spain, Portugal, and southern European countries, on the other hand, per capita consumption of salted fish has risen appreciably over the last decade (12).

These trends partly result from the fact that various European countries are at different stages of economic development. The trend towards higher consumption of better quality fish in higher income countries reflects the increasing income levels. The same is seen in the trend towards consumption of more costly processed fish. The latter development has also been facilitated by the technical break-through in quick-freezing. In the less developed countries in southern Europe, fish consumption levels have been influenced by the circumstance that foodstuffs are generally scarcer than in higher income countries; this produces a more direct relation between increase in income and increase in quantity consumed.

Price and income

As already mentioned, the effective demand for a product at any point in time is a function, *inter alia*, of its market price and the prices of substitute commodities. The degree of response which demand exhibits to changes in the price of a commodity reflects the intensity of the desire by consumers for it, and the existence of close substitutes. The demand for basic necessities of life tends to be inelastic, and that for luxuries elastic. What constitutes a necessity or a luxury, however, is essentially something that consumers (not, say, physiologists) decide, although within any one society or class there tends to be fairly general agreement on what is a luxury item and what is a basic necessity.

From monthly data covering the period 1954–57, J. A. C. Brown found that the own-price elasticity of demand for fresh and cured fish in Great Britain was 1·15 (13). This means, for example, that a 1 per cent increase in the price of fish would tend to produce a decrease in demand of 1·15 per cent.

The analysis by Brown illustrates the necessity of breaking down the demand into groups of products which are more alike in character. The own-price elasticity of fresh white fish, for example, was found to be 2·04, whereas that for cured fat fish was only 0·58. This finding confirms what would be expected on *a priori* grounds. Cured fat fish is relatively cheap compared with substitute commodities; and the products themselves are sufficiently distinctive in the minds of consumers that the elasticity of substitution between them and other foodstuffs is in any case relatively low. Fresh white fish, on the other hand, is more expensive and is a much closer substitute for meat. For both these reasons the own-price elasticity of demand tends to be higher for fresh than for cured fish. Appendix II gives the own-price demand co-efficients from a similar study covering the period 1954–59.

Meats are generally considered the nearest substitutes for fish, so that, if the price of meat rises relative to that of fish, there will tend to be some substitution of fish for meat. Econometric studies providing data on the elasticity of substitution, or cross-price elasticity of demand, are not as common as those of own-price elasticity. For the United Kingdom, however, R. Stone, using annual data relating to 1920–38, obtained a co-efficient (between the price of carcass meat and fresh and cured fish) of 0·85, indicating that a 1 per cent increase in the price of meat would *ceteris paribus* cause the demand for fish to rise by 0·85 per cent.

In general, both these own-price and price substitution co-efficients are relatively high. This suggests that effective demand could be increased or decreased appreciably by varying the average level of fish prices relative to incomes (or prices in general) and also by varying them relative to those of meat. These findings are only valid, however, over the range of prices which were realized during the period covered. They would not hold over an unlimited range either upwards or downwards.

The effects of changes in income levels on demand and expenditure are considered next. Income-demand (quantity) co-efficients show how the demand for a commodity tends to change with changing per capita income, while income-expenditure co-efficients show the relationship between income and expenditure on a per capita basis. To simplify matters, goods are often placed into two groups: those for which the demand (or expenditure on) increases with income, and those for which it decreases with income. The latter are termed "*inferior*", in that demand or expenditure is transferred from them to other goods as the standard of living increases. The division is rather arbitrary, however. Products which are loosely termed "*luxuries*" are characterized by high positive elasticity, "*inferior*" products negative elasticity; all other goods range in between.

There is a growing body of data on income-demand and income-expenditure relationships in different countries. From general observations one would expect that, for many commodities, expenditure co-efficient in the higher income countries will be higher than the demand co-efficient, since the trend in consumption tends to be towards better quality and service rather than simply increased quantity. The difference between the two co-efficients might be called the *income-quality demand co-efficient*.

The FAO Secretariat has summarized the findings of 50 national surveys of household consumption patterns of the main farm products and, by comparative analysis, has been able to arrive at further generalizations of income-demand and income-expenditure relationships. As fish occupies a relatively minor rôle in the consumption patterns of most countries, it is not always included in studies of the demand for foodstuffs, or is included only together with meat. Nevertheless, in the FAO study separate data on fish consumption were included for 20 countries.

From these surveys, it was found that the co-efficient of the elasticity of *expenditure* with respect to income varied generally between 0·5 and 1·0. The elasticity was below 0·5 in the Netherlands (0·37) and in the United Kingdom (0·38) among European countries as well as in the United States (0·27), Puerto Rico (0·20) and Panama (0·17). Demand elasticities were computed in fewer instances, but, as could be expected, these were lower, ranging from 0·0–0·66 (14).

The above co-efficients must be interpreted with caution, since they refer to all types and forms in which fish is consumed. Between these, the elasticity can vary considerably within a country. The average co-efficients, therefore, will only be valid through time, if at all, if the relative availability of the various types and forms continues unchanged. The variation in co-efficients between types can be seen from the case of Great Britain. The average expenditure co-efficient was 0·38, but the National Food Survey Committee data from which this estimate was made show that the co-efficients of the main types and forms varied from − 0·18 to + 1·18, which by any standard is considerable (15). The composition of the average, in fact, shows some interesting features. Fresh white fish is an important component at all income levels. On the average, it accounts for roughly half of the total fish consumption per head. This co-efficient (0·36), therefore, although slightly below the average for fish as a whole, greatly influences the latter. Processed white fish, on the other hand, had a co-efficient much above average (0·64), though that for processed fat fish was much lower (0·31). The co-efficient for fresh fat fish other than herring was almost unity (0·99), while that for fresh herring was particularly low (0·07). The co-efficient for shellfish was the highest of all (1·18), and that for cooked fish—fried fish from the fish and chip shops—was particularly low at −0·18. The latter was the only negative elasticity, indicating an "inferior" good. The co-efficient indicates that a 10 per cent rise in income per head tends to be associated with a decrease in expenditure on cooked fish of 1·8 per cent.

In a more recent study by the National Food Survey Committee relating to 1958, the income-demand as well as the income-expenditure elasticities were calculated (see Appendix III). Comparison shows the extent to which the former lie below the latter. While there is a fairly close correspondence between the 1955 and 1958 results, some of the absolute differences are quite large. It is clear, therefore, that too much importance should not be attached to the co-efficients of narrow groups derived from any particular study.

The national average elasticity co-efficients (and the more detailed ones for Great Britain) correspond to the average total expenditure of the populations to which the surveys apply. The fact that they are simply constants leaves open the question of whether the elasticity may vary at very different levels of real income. A means of exploring this possibility is to compare the size of the co-efficients in countries with different income levels. In the FAO study referred to, it was found that the elasticity of expenditure decreased with the level of income in the case of some products, particularly meat, milk, eggs, sugar products, cereal products and starchy roots.

The data on fish showed that there did not seem to be any close negative correlation between the value of the elasticity co-efficient and the standard of living. This is perhaps not altogether surprising and helps illustrate the limitations of this type of study. In making such comparisons, there is the implied assumption that what is seen to occur between countries with different levels of real income per head gives a guide to what can be expected within any country through time as income per head rises. Fish is a good example of how this approach can run into difficulties. Ways of life differ enormously between countries; so does the availability of various foodstuffs. International comparisons are only likely to produce meaningful results for commodities basic to all the respective countries and, more particularly, only when they relate to populations having the same ways of life, similar general preference systems, and similar relative scarcities of commodities, or similar factors of production needed to produce these commodities.

These conditions are far from satisfied in the case of fish. Tastes are not "God given" but, in part, tend to be handed down from generation to generation. They are closely related to the availability of the various commodities over the long term past.

The considerable variations in the ease of access to good sources of supply of fish have produced considerable differences in the preference for fish. The economic difficulties of distributing to inland areas have produced similar differences. It cannot be expected, therefore, that this kind of international comparison will produce valid or meaningful results for fisheries.

Although international statistical comparisons do not show it, it would seem reasonable to expect that the income-expenditure elasticity for fish will tend to decline in any country, as real income per head increases. The elasticity of *demand* for food in general is likely to decline, if only because the capacity of the human stomach is limited. It might be expected that the elasticity for fish will tend to follow the general pattern. Tending to maintain the expenditure co-efficient will be the trend towards higher quality, including increased processing and additional services on the distribution side. The trend towards quick-frozen consumer packs of fish is an example of this. This subject is, however, somewhat abstract and its analysis inconclusive. The realized changes in these co-efficients over any very long period of time (and it is only over the very long period that changes in the co-efficient resulting from income changes can be material) will be determined largely by the inventive genius of those who engage in the development of new ways of processing and marketing commodities. This is a field where it would seem particularly dangerous to assume that past trends will continue into the long term future for any specific commodity.

This danger is much increased by the fact that, as mentioned, these co-efficients are derived from budget study data of a cross section of the population at a point in time. They are, therefore, static co-efficients. Their practical value lies in the extent to which they provide a clue on what to expect through time, which is essentially a dynamic setting. To say that fish expenditure per head increases with real income in the ratio of, say, 38 : 100 at a point in time does not mean that, when average real income per head has increased by 10 per cent, average expenditure per head will have increased by 3·8 per cent.

Relation of supply availability to demand

In economically developed countries, it is sometimes remarked, fishing is the last pursuit where man continues to hunt for food on any large scale. The fact that supplies of fish are obtained in this manner and that, once caught, fish is highly perishable, has several adverse consequences on demand. Four of these may be considered, viz: (a) changes in the fishing regions; (b) seasonality of supply; (c) daily fluctuation in price; and (d) uncertainty regarding quality.

(a) **Changes in Fishing Regions.** As the population of Europe has increased, it has become necessary to obtain increased supplies from more distant fishing grounds, particularly in Arctic waters. In many southern European countries, where hard-cured fish has long been widely consumed, this trend has not had a very great impact on demand. But in the more northerly countries, where such cures are not generally acceptable, it means that the quality of the fish has tended to decline. This has occurred despite faster vessels with improved holding facilities. The vessels fishing in Arctic waters are away from port for between 2 and 3 weeks each trip, and it has been estimated that at least half of the fish brought from distant-water grounds is more than 2 weeks old when landed (16).

Scientific investigations in different countries have shown that "even when the utmost care is taken in handling, and the fish is perfectly treated and kept at 0°C, commercially important species of white fish, such as cod and haddock, cannot be kept for more than 12–14 days before putrefaction sets in". It is obvious, therefore, that generally the quality of this distant water fish will be lower than that landed by the inshore fleets (17).

Moreover, the greater part of the catch from these grounds is of less valued fish, particularly cod. It would seem that such fish must form the bulk of any increased supplies of white fish in Europe. This is one of the most important factors preventing fish consumption from rising in many countries. For, while the demand for the more esteemed varieties of fish—halibut, sole, hake, plaice, etc.—is strong, and the price relatively high, the large supplies of cod (and herring) have pushed down prices to the extent that in more and more European countries fisheries are not economic and have to be subsidized in one form or another.

(b) **Seasonal Fluctuations of Supply.** Due partly to the movements of fish populations, and partly to the dependence of fishing vessels on favourable weather conditions for maximum productivity, the supply of fish is subject to seasonal fluctuations. For any country, the seasonality of a particular species can far exceed that of fish in total, which again illustrates the danger of over-simplifying the analysis of the demand for fish by assuming "all fish to be much the same". Whereas the limit of consumption of cod—at economic prices—has been reached in a number of countries, the annual consumption of a number of other varieties would certainly be higher in Europe if supplies could be sustained over the year instead of being restricted to only certain seasons.

Even for the common varieties, supply is not geared to demand in the most economical manner. Whereas demand in most countries tends to be higher in winter than in summer, supply does not vary to the same extent. The consequence is that prices are higher in winter than in summer. Moreover, due to the longer average trip time of the distant water vessels in winter, quality is generally poorer at that time of the year.

In short, while nature has given us a bounteous harvest in the sea, the production and supply of sea fish cannot be adapted to demand in the manner which would maximize consumption.

(c) **Daily Fluctuation in Price.** A consequence of the uncertainty inherent in fish production methods and the variations in catching is that supply fluctuates very considerably around the average on any given week-day; and these unpredictable fluctuations in supply produce serious disadvantages to the consumer where fresh and lightly cured fish are concerned. In the extreme case it can mean that the housewife (representing the typical buyer at retail level) cannot obtain the variety of her choice just when desired, or cannot do so at the price she is prepared to pay. Where the distribution network is well developed, so that retailers can directly or indirectly draw on supplies from several ports, these variations will tend to be less than where supplies are limited to, say, one port. Such fluctuations are never entirely obviated, however.

The fluctuations in supply produce day-to-day fluctuations in wholesale and retail prices—except in completely controlled conditions. The price mechanism is simply a method of distributing the current supply to those would-be purchasers who are able and willing to pay the current price. Because of the fluctuations in supply relative to demand, however, prices fluctuate from day to day. This frustrates the housewife almost as much as the variations in supply.

(d) **Poor Quality.** The poor quality of some fish, and all fish in some areas, as already mentioned, inhibits demand. A related factor, but one which probably restricts demand in virtually all areas where fresh fish is marketed, is the uncertainty in the housewives' minds regarding the quality of the fish offered. This uncertainty is related to variability in quality, which is partly a consequence of the way supplies of fish are obtained. This factor is, of course, not peculiar to fish, but can be of particular significance in relation to this commodity and may be an important repressing influence on consumption.

In a consumer survey carried out in Great Britain (18), for example, roughly half the respondents agreed with the statement that "one always has the suspicion that fish might not be quite as fresh as it ought to be". A similar proportion agreed with the statement that "there is no guarantee of freshness". Roughly half these respondents considered this latter point to be a serious disadvantage of fish. It might be pointed out that, if this attitude towards fish is widespread, but does not apply to other foodstuffs, this will repress the demand for fish and favour other foodstuffs, whether or not the same indifferent and variable quality occurs in the supplies of the latter. It is the different attitudes that count in demand.

Canning, bottling, quick freezing, salting and drying, by reducing the rate of deterioration of fish, can help control the quality of the product during distribution to the consumer. Except for quick freezing, these processes, however, also change to varying extents the flavour of the fish. This is not necessarily to the detriment of fish demand as a whole. Smoke curing, for example, which began as a means of preserving fish and allowing extended distribution is, in Great Britain at least, now largely undertaken because there is a demand for fish in this form; dyes are even used in the trade to give fish the appearance of having been well smoked when it is not. The other processes can similarly increase fish demand, since they increase the diversity of fishery products and hence variety in diets. Although beneficial in this way, therefore, these processes do not afford means of improving or standardizing the quality of *fresh* fish when it reaches the consumer. The growth of quick freezing has materially changed the position, however, although sales in consumer packs, as yet, form a relatively minor part of total fresh fish sales. If quick freezing at sea continues to develop, however, this could have revolutionary effects on the average quality of "fresh" fish reaching the consumer from distant water grounds in the Arctic and from the African coasts.

Another development which may prove important in this respect is the use of antibiotics. When added to the ice, the rate of deterioration of fresh fish is markedly reduced. This could prove the means of materially improving and controlling the quality of fresh fish. As yet, this method would seem to be largely in the development stage; and in the United Kingdom the use of antibiotics for this purpose is prohibited by law.

Institutional factors and tastes

There are several important demand determinants, whose impact on consumption is extremely difficult to quantify. The following may be mentioned: availability of retail fish outlets and of transport facilities, standards of hygiene in distribution, consumer tastes and habits, and sales promotion. These factors have one element in common: changes are effected only slowly through time. In econometric analyses based on time series, changes in these factors may be allowed for by a catch-all residual trend variable. Where a strong trend of this character remains after allowing for the effects of income and prices, this technique is extremely valuable. For example, given such trends, any projections based on income and price co-efficients alone would produce rather spurious results.

In the study by Stone referred to earlier, it was found that, after allowing for income and price changes and substitution effects, there was a residual downward trend of roughly 2 per cent per year. This much outweighs the increase in demand which it was estimated would follow from the rising level of income per head.

The income elasticity co-efficient used in this case was calculated from budget study data, and therefore is subject to the same limitations as explained earlier. For this reason, the trend factor might be considered to illustrate, not the changes in tastes of the population under consideration, but rather the fact that it is false to assume the preferences of individuals at one position on the income scale to be the same as those of individuals at, say, a higher position on that scale; and, hence, that the individuals in the former group will, *ceteris paribus*, reveal the same preferences as the latter group when, at a later date, they enjoy the income that the higher group then enjoyed. Or, in other words, that it is false to assume that preferences do not differ radically between income groups at any point in time.

Ignoring this point, the residual trend co-efficient not only contains the effects of changes in tastes, but also those of any other factors not taken into account in the analysis. The trend co-efficient, therefore, is the net effect on demand of an unknown number of influences. Without information on the factors producing this trend it is difficult to know how stable it is likely to be.

It is natural to assume that changes in consumer tastes are the principal causes of these trends, but institutional factors can also be important. Moreover, tastes can change for different reasons and, in particular, such changes can be induced by sales promotion techniques.

The lack of retail outlets for fish has already been mentioned in connection with the differences between urban and rural consumption levels. The OEEC survey referred to earlier makes repeated references to this point (19). In the Federal Republic of Germany, for example, it has been found that towns of less than 10,000 inhabitants, which account for 40 per cent of the total population, have proved too small to support even one specialist retail fish shop (20). The extent to which the lack of specialist outlets prevents demand from becoming effective depends, of course, on the particular preferences of individuals; by and large, only fresh and lightly cured fish tend to be sold through specialist outlets. Canned and bottled fish is retailed normally through grocers; and in countries where hard cured fish is enjoyed it, too, is retailed through these channels.

As far as fresh fish is concerned, however, the lack of outlets can be, and is, a serious handicap to consumption, and it is difficult to see how this can be overcome. In some countries mobile shops have been encouraged but, in the main, thinly populated areas are poorly served with fresh fish.

The development of quick freezing is proving beneficial in this respect. While it may be argued that quick frozen fish is not fresh, quick freezing changes the taste of the product much less than any other means of preservation; and fish preserved in this way can taste much more like fresh fish than stale "fresh" fish. In Great Britain, surveys have shown that the consumption of quick frozen fish is relatively high in areas where, previously, other fish consumption was low, due to distribution difficulties. The same trends are evident on the continent of Europe.

Quick frozen fish is relatively expensive to produce and distribute. In particular, it requires a "cold chain" through which it can be distributed. As it is impracticable in any country to set up such a chain for fish alone, the development of fish consumption of this type must await the general development of quick frozen food sales. Such sales are increasing rapidly in high income countries, but in others it seems unlikely that development along these lines would be economic under present circumstances.

A factor which undoubtedly depresses demand, yet which is largely in the hands of the fish trades themselves, is the standard of hygiene practised by distributors of fresh and cured fish. At the large ports, for example, the practice of laying out fish for auction can be very detrimental to quality.

Similarly, standards of hygiene in retailing frequently leave much to be desired. Fish is still retailed by hawkers in some areas and they seldom have the means of maintaining the products in good condition. In non-mobile establishments the use of cooled slabs and cabinets is increasing in many countries, but all too often the retailer displays his fish in the traditional manner on stone slabs in the open shop front. Such a display can be very appealing to the eye, but the summer heat, dirt and flies quickly reduce the products to a much less-appealing condition by the time they are eaten.

In most areas of Europe the transport of fresh fish, as such, does not seem to present great problems, although in some countries the quality does suffer appreciably during transit (21). The carriage of fresh fish is, of course, very exacting on transporters. Fresh fish cannot be loaded indiscriminately with other goods, and speed and punctuality are essential. For these reasons, some shortcomings in transport facilities to areas of low consumption would seem inevitable. Unless those living in these areas are prepared to pay a much higher price for their fish, however, or unless official assistance is given, it is difficult to see how the situation can be altered.

Consumer tastes and habits in fish, as in other foodstuffs, have changed over the years more and more towards "ready-to-cook" and "ready-to-eat" products. Whereas at one time consumers generally preferred fresh fish "on the bone", over the last few decades the trend has been more and more towards fillets. Canning and bottling allowed much wider distribution of fish; and as the fish was, and still is, mainly in a ready-to-eat form, this gave it a special appeal to housewives. More recently the development of quick frozen pre-cooked fish has proved to have the same appeal.

The final determinant which will be considered—sales promotion—can also be, as is well known, one of the most potent influences on demand. While not unique in this respect, fish has been handicapped by the difficulty in branding fresh fish. Since most advertising is done by the producers of products, the inability of fresh fish producers to brand their products has meant that there has been no simple means of offering counter-inducements to other products.

In most countries sales promotion has been undertaken in one or more of its forms—including consumer education campaigns (22). Collective advertising of "fish" has been carried out in certain countries either by the industry or by official agencies. The key to successful advertising, however, is control over the quality of the product. With fish this has not been done on an industry basis. The development of quick freezing will again help in this respect, since the products can be branded and the name advertised. It is unlikely, however, that any very effective means will be found to brand and advertise fresh fish; and it is fresh fish which will form the mainstay of demand in most countries for many years to come.

What the industry can do to increase demand

To help to even out the supply of fish through time, port wholesalers (and, to a lesser extent, retailers) vary their carry-over stocks according to their knowledge and expectation of supplies the following day. This is not practised in all countries, but varies according to the climate and the facilities possessed by the sellers. In Greece and Italy, for example, where retailers' premises are frequently relatively primitive, and where often no means are used for preserving quality, such holding-over is not possible. In the more northerly ports of Europe, however, the practice is more common (23). On the price side, distributors, particularly retailers, do not necessarily work to a fixed profit margin. Instead, they raise and lower selling prices less than in proportion to their buying prices, in an effort to reduce price fluctuations. The variations are further reduced by the fact that certain distribution costs, for example, transport and boxing, do not vary with the price of the product.

The amplitude of the fluctuations in supply passing into consumption, and in selling prices at all stages of distribution, is reduced by the imposition of minimum selling prices at first-hand sales. These minima may be fixed by the fishermen or their appointed salesmen or, in some cases, for example in Norway, by official agencies. These minima provide a price floor. The overall net advantages or disadvantages of this practice are not relevant here. What is relevant is that this form of regulation prevents prices from reaching very low levels. At least in the short run, this keeps prices higher than they would otherwise be and prevents some supplies from reaching the consumer in times of glut.

In some countries (for example Portugal) prices are constrained in an upward direction by the use of maximum selling prices. In general, however, the difficulty of administering such a policy makes it uncommon.

It can be seen, therefore, that in many cases the housewife is protected in different ways from the worst of the fluctuations in supply and price; but in the case of minimum price fixing, only at the cost of not being able to buy particularly cheap fish during periods of heavy landings. Moreover, in Great Britain, a country where such practices can and do impart considerable price stability at the point of retail sale, it was found, from the consumer survey previously referred to, that fluctuations in retail prices were still an important factor operating against the greater consumption of fish (24). Roughly three-quarters of the respondents agreed that "the price of fish is always changing"; and half of these considered this to be a serious, or quite serious, disadvantage of fish. This latter proportion was highest among the lower income groups and amongst those unfavourably disposed to fish.

The trend in other food trades is towards improved grading to reduce quality variability and thus to give the purchaser greater confidence in the particular product in question. To a limited extent this has occurred in the fish trades; but to prevent the position from becoming increasingly unfavourable through time, it seems very desirable that greater emphasis be placed on this point. Once sellers have improved grading to the point where consumers feel that they do "know what they are buying", demand can be strengthened, and sales stimulated, by branding. Branding, like all advertising, however, is useless, and may even be detrimental to sales, unless quality can be controlled within limits acceptable to the consumer.

In most European countries, official or unofficial measures of some form are taken to regulate quality. Frequently these take the form of official inspections of the fish when it is landed to see whether it is fit for human consumption. Unfortunately, objective tests of quality which can quickly determine the state of the fish are not as yet available; and when vessels are away from port for a considerable number of days, the variations in the quality of the fish landed by the same vessel can be so great that sample inspection is not appropriate. Moreover, tests carried out on landing, while valuable, are far from adequate to control the quality when it reaches the consumer. Their purpose is usually to determine whether the fish, at that time, is fit for human consumption. Inspection at the inland wholesale and retail markets goes a little farther towards the ultimate objective; but there can still be a considerable difference between fish which is fit for human consumption and good quality fresh or cured fish.

There is much that could be done to improve quality by raising standards of hygiene in distribution. Fish consumption is not likely to increase appreciably if the quality is variable and, not infrequently, poor. The inherent characteristics of fish and the nature of its supply make quality control difficult; but the fish trades should do everything economically possible within their control to see that quality does not suffer more than is inevitable.

In comparison with many other foodstuffs, especially meat, fish consumption has probably been adversely affected by the lack of development in the canning of the important species of white fish. An acceptable canned product amongst the more common varieties of white fish could probably do much to raise consumption. The development of quick-frozen pre-cooked fish will help to stimulate, or at least to maintain, the demand for white fish. But the inability of the catching industry to obtain appreciably increased supplies of the more esteemed varieties, particularly flat fish, is likely to restrict the increase in consumption of fish in general. As income levels increase, consumers will tend to look for better quality foodstuffs. If these are not forthcoming, more and more of the increase in total consumption of, and expenditure on, food will go to close substitutes for fish.

In the southern European countries, however, where standards of living generally are lower, and where hard-cured fish, more particularly cod, enjoys a relatively high consumer preference, one would not expect this restriction to have as much force.

Conclusions and outlook

From this brief review of fish consumption trends and determinants, it would seem that nothing dramatic can be expected to happen over the foreseeable future. The income elasticities of demand suggest that a relatively high positive relationship exists in most countries. On the other hand, over the past decade, aggregate consumption has only managed to keep pace with the growth in population; although, as the years from the end of World War II to the early 1950's were affected by the dislocations of the war, too much weight should not be attached to comparisons with those years. To some extent the lack of growth in consumption per capita could have been due to an adverse trend in fish prices relative to meat, but insufficient data are available to check this point. It would seem probable, however, that, on the basis of income elasticities computed from cross section or budget study data, one should allow for a residual downward trend in demand per capita.

In contrast to most other foodstuffs, the supply of fish is contingent upon the ability of the fishing fleets to locate and catch the fish in their natural locations. This results in appreciable unforeseeable fluctuations in supply, price and quality; and demand is probably adversely affected by these. The diminishing returns from increased fishing in waters surrounding Europe has necessitated increased effort in the more distant waters. The greater part of the catch from these grounds, however, is of the common varieties of white fish. The demand for such fish cannot be stimulated appreciably by price reductions since, generally, such fishing is, at current prices, only marginally economic. The relatively high price elasticities of demand which appear to exist, therefore, are unlikely to be influential in increasing consumption in the future.

Although the effects cannot be quantified, it would seem reasonable to suppose that demand would be appreciably stimulated if distribution facilities for fresh and cured fish could be improved in the more thinly populated areas, and if the standards of hygiene were raised in the trade generally. The potentiality of stimulating demand through canning and bottling pre-cooked fish of the common varieties of white fish has not been realized to date. Consumption has probably been adversely affected by counter-attractions of this kind found in other foodstuffs, as it has by the inability to brand fresh fish products to help stimulate demand or even counter the effects of advertising of substitute products.

The development of quick-freezing has undoubtedly opened up new avenues in this respect, and could do much in the long run to overcome problems of distribution and sales promotion. For some considerable time, however, such fish is only likely to be consumed on any large scale in the higher income countries.

In conclusion, therefore, it may be said that there is no reason to expect important changes in the overall trend in the consumption of fishery products. The relatively high income elasticities give grounds for believing that consumption levels will tend to increase with income, although such co-efficients by themselves probably over-state the case. On past showing, it would seem prudent to expect little change. While demand could be expected to respond significantly to price reductions and to improvements in distribution facilities and trade practices, and in more forceful sales promotion, it would seem unlikely that the current situation will change rapidly in the future.

PART III. THE DEMAND FOR FISH IN NORTH AMERICA

Both in Canada and in the United States, fish consumption is relatively low compared with many countries of Western Europe and Japan, for instance (25). The United States covers a third of its market requirements by imports. Canada, however, produces enough fish to be able to export approximately two-thirds of its catches (two-thirds of exports being destined for United States markets). Canada thus ranks with the leading fish exporting countries of the world, together with Norway, Japan and Peru.

In recent years, utilization of catches for human consumption has not kept pace with population growth in the United States. Even when measured in absolute figures there has been a decline. At the same time, utilization of catches for industrial purposes has been steadily increasing, up to a point where today the quantities used in animal feeding and in the manufacture of industrial products are similar to those used in supplying the market for human consumption (26). This strong emphasis on industrial fish catches is considered rather exceptional for a fully-developed country (27). No one explanation can account for the overall trends in food and industrial fish utilization. The reasons usually cited differ from fishery to fishery, and include a wide variety of natural factors (changes in water temperature, in ocean currents, diminution of food in the sea, overfishing, pollution, etc.), of economic and social factors (changes in costs, in trade policies, recruitment problems, etc.), and of technological factors (obsolescence, development of innovations, etc.).

On a per capita basis, consumption has remained fairly constant over the years, both in the United States and Canada. Gaps in United States requirements have been made up by imports. During the war, scarcities in supplies of competitive foods spurred consumption of some fishery products (although restrictions on the use of packaging materials drastically curtailed sales of some other, notably canned, products). These conditions are said to have affected consumer habits beyond the wartime emergency period.

Minor fluctuations in per capita consumption levels since the end of the war seem to have been attributable to changes in the price relationship between fish and competitive products, particularly meat, but were not indicative of any basic trend. Distinct changes in trends can be discerned in the composition of per capita consumption by form and type of product. These trend changes will be discussed in a later section.

The competitive relation of fishery to other animal protein foods

Food items compete with one another. They compete on a nutritional basis. But, more than this, they compete also in terms of a variety of other criteria, such as the time needed for the preparation, suitability for use in certain dishes, position in the menu in general, etc.

"The fact that different foods, such as beans, cheese, eggs and fish, are equivalent sources of protein", in the words of one authority in the field of demand analysis, "does not necessarily lead to economic competition among the foods. To the extent that custom and time needed for preparation made eggs a breakfast and meat a dinner item, the two compete very little" (28).

Fish competes with meat and other animal protein products and, to a lesser extent perhaps, with other food products also. There is competition, furthermore, between fresh and frozen and otherwise processed products; between different species of fish; and between differently packaged and prepared fishery products. Competition is affected by regional, cultural, economic, technological, and a host of other factors. In this section, only the general relationship between fish and other food products is considered.

Cassady concludes, on the basis of a comparison of per capita consumption rates, that the United States is essentially a meat-consuming country (29). On the average, the consumer eats about 15 times as much meat a year as fish. Since meat, in turn, represents only 10 per cent of the total annual food intake, fish cannot be considered a very important component of the diet.

Trends in per capita consumption rates of fish and of its closest substitutes (which include chicken, eggs, and cheese in addition to meat) show a significant increase in the consumption of chicken and eggs since before the war, and a more modest increase for meat in the postwar years (30). Fish consumption, in contrast, as already pointed out, has not changed materially over the years.

Canadian per capita consumption data show very similar trends. Using the 10-year period from 1947 to 1957 for illustration purposes, one finds, for instance, that average consumption of red meats increased by 10 lbs., and that of poultry by 20 lbs., while fish consumption remained fairly stable.

Compared with annual per capita consumption figures, data obtained in connection with household surveys represent only a part of the picture. They are based on sample interviews. They relate—as carried out in the United States and Canada—to a selected 1-week period only, and do not—by definition—include institutional consumption. The data collected in consumption surveys, however, permit an analysis by income class, geographic region, size of household, and provide particulars, in addition to quantities consumed, on dollar expenditures and on percentage of usage. In the United States, surveys of average weekly household consumption were carried out in 1948 and 1955; in Canada, in 1953, 1955 and 1957.

The United States' surveys confirm that fish is not improving its position with respect to meat and poultry. Whereas the percentage of households using poultry increased from 35·2 to 47·9 from 1948 to 1955, there was virtually no change in the usage rate (56·6) for fish. Further, in 1955 weekly consumption of meat and poultry was 11·9 and 36·1 per cent, respectively, above 1948 levels, while the quantity of fish eaten showed a small decline of 1·1 per cent (31).

In terms of dollar expenditures, however, the difference in trend over the same period between fish and its closest competitors is less pronounced. Measured against total food expenditures there were declines in the proportions spent on meat as well as on fish, although the absolute expenditure on each increased slightly. Both the absolute, and the proportion of total, expenditure on poultry increased, however (31).

The Canadian data (based on surveys in 5 cities) also confirm that fish has been losing ground in that country, again relative to poultry, in particular. In 1957, thus, expenditures for fish were only 58 per cent of those for poultry as against 1953 when this percentage was as high as 72. Average weekly family expenditures for meat were approximately 10 times as large as those for fish. Measured against this total food budget, the expenditures for fish represented only a modest 2 per cent portion (32).

To make the comparisons complete, similar data for institutional consumption are needed, particularly for consumption in public eating places. Food consumption outside the home has been on the increase in North America in the postwar years. It is known that markets for fish as well as for meat and poultry have benefited from the expansion of the restaurant business. In the absence of statistics comparable to those available on household consumption, relative progress made cannot be documented. In terms of total sales for consumption, fish and shellfish meals served in public eating places were estimated to have amounted to about one-fourth of total fishery products marketed in the United States (33).

The big increase in the consumption of poultry products in North America has been said to reflect substantially lower prices relative to livestock products as a whole, as well as relative to all farm products. Cross-price elasticities of demand for fish with respect to other products have been computed for a number of species and at a number of different time periods. The studies bear out that prices of fish relative to those of competing products have a close inverse relation to consumption. The evidence suggests, though, that the relationship is closer for some species or products than for others and that fish consumption will tend to be more substantially affected by a drop than by an increase in prices of competing products.

Summarizing results of studies carried out by himself and by other experts, Crutchfield concludes as follows:

"In the case of halibut, the correlation between a weighted average of prices paid producers of meat animals with Seattle prices for halibut ex-vessel is quite apparent, since strict regulation of the total catch after 1933 reduced short-run variations to very low levels. The relationship between mean prices and total landed value of the halibut catch is, of course, even closer. In the case of salmon, supplies of which were moderately expansible (during the period covered) the relationship is less clear, but a comparison of troll landings with year-to-year meat-salmon price relatives shows the anticipated inverse correlation. Herrington and White drew similar conclusions from comparisons of price relatives for cod and haddock to meat with landings of these species in New England ports.

The influence of meat prices is much less evident in the case of trawl-caught fish and the miscellaneous minor species which are closely competitive in the regional (i.e. Pacific Coast) market. To a large degree this may be attributed to the swamping effect on prices and output of the notable technological changes in the fishery. In addition, the somewhat divergent movements of salmon and halibut prices to those of the cheaper species suggest that market averages of items at the opposite ends of the chains of imperfectly substitutable fishery products is far from uniform with respect to both geographic inclusiveness and classes of purchasers. Changes in meat prices are probably transmitted to demand for lower-priced species indirectly via their effects on prices and output of the more desirable fish, and with some degree of dilution" (34).

Commenting on the results of the Canadian surveys of food expenditures of urban families, Frick concludes as follows on cross-elasticity:

"There is no evidence of a significant degree of cross-elasticity of demand for fish in terms of the price of beef or pork, since apparently there was little substitution of fish for either when their prices were high. Such an effect could have been masked, of course, if fish were purchased instead of beef in one period and instead of pork in another as their prices moved in inverse directions—with the annual level of fish consumption remaining more or less constant. Any substitution effect must have been small, however, because the total per capita domestic disappearance of fish was small" (35).

A clue that price elasticity and the substitution effect are different for different price ranges comes from a study of the marketing of fresh fish in three selected markets in the United States carried out a few years ago. Commenting on conditions in the Cincinnati market, a buyer for a large grocery chain expressed the view that the demand for fish was highly elastic above a certain price, but below this price—or narrow range of prices—became highly inelastic: "The critical point beyond which demand . . . was influenced by price varied. It was related to the price of meat, particularly poultry, but was also related to non-meat items such as macaroni products which tended to have prices which were more stable than meat prices" (36).

The demand for different forms of fish products

Although overall per capita consumption of fish has remained quite stable, there have been very distinct trends in North American markets for different forms of fish products. In particular, there has been a modest decline in the consumption of canned products, and a more pronounced falling off in the relative consumption of cured products. These declines, however, have been compensated by increased consumption of fresh and frozen products.

As far as the group aggregate for fresh and frozen products is concerned, statistics are difficult to break down into the two components. Among other reasons, this is because considerable quantities of frozen fish are thawed and kept on ice in retail establishments and sold as "fresh fish". Cassady speaks of a tremendous shift in consumer demand away from fresh fish and toward packaged quick-frozen fish in certain areas in the United States since the end of the 1930's. This trend, he concludes, has contributed both to a reduction of outlets handling fresh fish and to the substitution of low-cost for high-cost distribution methods (37).

The important rôle of processing, in general, in the utilization of catches in North America (almost two-thirds of total production are sold in other than fresh form) is explained by the seasonality of the fisheries. Nearly three-fourths of total catches, thus, are taken in the second and third quarters of the year (38).

Trends in the consumption of different products are not necessarily related to competitive factors. In many instances, they are traccable to changes in consumer habits and preferences and to other determinants. Absence of a competitive relationship between canned, and fresh and frozen, fishery products in the United States was clearly demonstrated, for example, in a study of the market for canned fish completed a few years ago. A higher percentage of canned fish actually was bought by users of fresh and frozen fish than by non-users of the latter products (39). Since the canned fish products which are most popular in North American markets are prepared from species not sold in appreciable quantities in fresh or frozen form, the lack of competition should not come as a surprise.

Expansion of the market for frozen fish is related to the remarkable development of the frozen food industry in general during and after the war. Technological and economic factors, primarily, are cited in explanation of the decline in salting and other curing methods. Development of technically satisfactory and economic methods of refrigeration, thus, has made possible the substitution of freezing for other forms of preservation, and higher incomes have brought more expensively processed products within the reach of the pocket of additional consumers.

The geographic pattern of consumption

Differences in the geographic distribution of population within a country have an important bearing on markets for fishery products. Borgström mentions in this connection that in the United States a larger proportion of the total population resides in coastal areas than in other countries of the West, e.g. those of Western Europe and the Soviet Union (40). Even in the United States, however, in spite of excellent communications, ample availability of cold storage, and a high degree of mobility of the population, there are still significantly fewer fish eaters in inland areas than there are in coastal areas.

Statistical proof is provided by the 1955 weekly household consumption survey previously cited. Results show that the proportions of total households which used fish and shellfish products in the survey week were significantly lower in the South and in the North Central regions than in the West and in the Northeast, which have long coastlines. The former proportions were 48·7 per cent and 49·5 per cent, respectively, whereas in the latter regions they were, respectively, 60·6 per cent and 70·9 per cent (31).

Income and other factors, however, tend to obscure geographic patterns. Consumption is known to be relatively high in some inland markets in the South where cheap fish supplies constitute an important component in the diet of low-income families. The 1955 survey shows in this connection that average weekly household consumption is higher in the South and the Northeast than in the other two regions. The expenditure data, though, indicate that the fish and shellfish purchased in the Northeast are high-priced, while the South relies on low-priced products.

What is already apparent, with respect to market geography, from the data for all fish, is even more clearly in evidence when markets for different types of products are considered.

The acceptance of frozen fish, for instance, as Cassady points out, has been far from uniform in all parts of the United States. The popularity of the product in this form appears to be greater in relatively low fish-consumption (i.e. inland) areas than in high-consumption (coastal) areas.

The demand in the South for inexpensive non-perishable products which are easy to transport and store, to cite another example, has favoured distribution of certain canned products, e.g. the cheaper varieties of canned salmon and canned pilchards.

Other geographic patterns recognizable from studies carried out show differences in consumption rates between communities with different population densities and between urban and rural areas, in general. Consumption of canned products in the United States, for instance, has been found to be greater in metropolitan than in non-metropolitan areas and greater in large cities than elsewhere (41). As far as consumption in urban and rural areas is concerned, both the percentage of households using fish and shellfish, and average weekly expenditures on these products, are greater in cities than in rural farm communities. Consumption in physical terms on the farm, when all sources, including fish produced on the farm, are considered, however, actually exceeds that in the city (31).

MacKenzie attributes the difference in the consumption pattern between urban and rural areas to the fact that distributive channels run through urban centres, and that a large proportion of the total consumption of fishery products takes place in public eating places and in institutions (hospitals, prisons, etc.) located in cities (42).

The demand for different species of fish and shellfish

Harden Taylor, in the general discussion of the economics of fisheries included in his book on the Marine Fisheries of North Carolina, expresses the view that: "... there are few fishes which have no equally acceptable substitute in the market; rather, the totality of most kinds of finfish collectively presses against the total market demand for any kind of fish. . . .

The economically important matter is the quantity and value of the total yield of the fisheries, regionally and nationally . . . the yield of the sea fisheries as a whole or of any considerable region has not only been sustained, but has generally increased with increasing human populations" (43).

A time series on the composition of United States catches (see Appendix IV for catch data for selected species) would seem to bear out Taylor's contention that, in the long run, substitution is no problem. Fish and shellfish which only half a century ago were virtually unknown to the consumer on the North American continent, e.g. tuna and shrimp, rank today first in importance. On the other hand, other species such as oysters and cod, at one time leading in market popularity, have lost considerable ground over the years.

Nevertheless, market substitution of one species of variety of fish for another is not automatic in the short run, at least not in North America. In contrasting the North American to the Japanese market for fish, Herrington, thus, at the recently held FAO Expert Meeting on the Economic Effects of Fishery Regulation (44), emphasized that the North American market accepted only selected species and sizes, whereas in Japan preference for fish was so pronounced, the consumer was ready to "absorb practically all varieties and sizes". A background paper on the regulation of the Japanese trawl fisheries prepared for the above meeting lent support to this (45). It reported that the Japanese fleet was able to shift—without concern for market implications—to production of "low-grade" species, when catches of "high-grade" species declined (croaker, and snapper, respectively, according to the Japanese expert who attended the meeting).

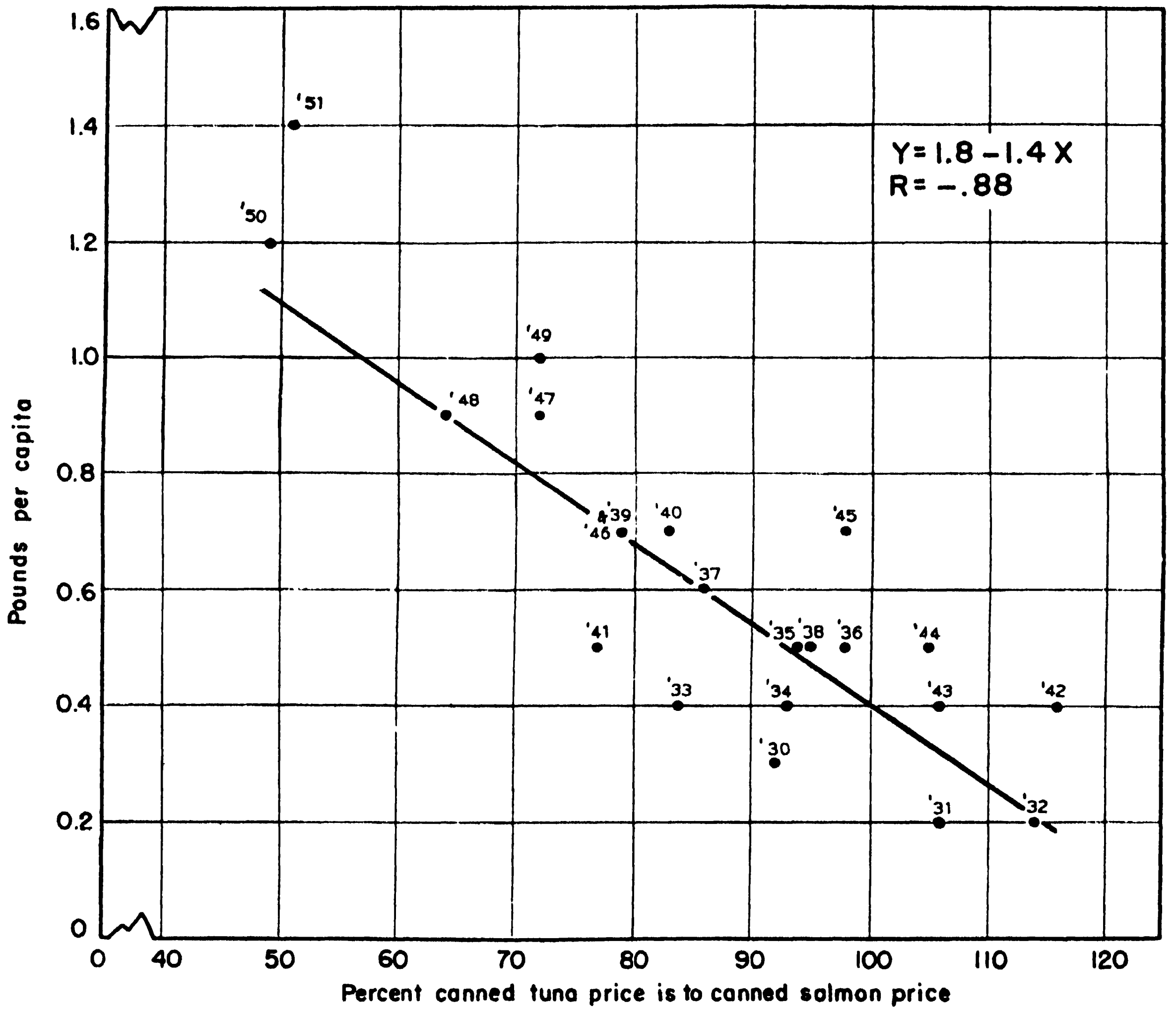
Taylor makes a clear distinction between fishery products in the luxury class which are not substitutable by similar products and others which are not *sui generis* and can be readily replaced by other products. Demand elasticities, both with respect to price and income, are higher for luxury items, such as most shellfish and certain forms of finfish used as expensive appetizers, than for the bulk of common finfishes. There are a few differences or price classes, he says, based on size and fat content but generally consumers can distinguish but poorly between the various species of finfish (46).

The views of Taylor and Herrington can be reconciled when it is realized that the former thinks of substitution in the long run and the latter of substitution in the short run.

More or less direct substitution of one species or

Figure 1

RATIO CANNED TUNA PRICE[1/] TO CANNED SALMON PRICE[2/]
RELATED TO PER CAPITA CANNED TUNA[3/] CONSUMPTION,
1930-1951.



1/ Weighted average wholesale price all packs including tunalike fishes.

2/ Weighted average wholesale price all packs.

3/ Tuna and tunalike fishes.

Reproduced from Survey of the Domestic Tuna Industry,
Special Scientific Report - Fisheries No. 104, p. 91
Fish and Wildlife Service, Washington, 1953.

product for another, available evidence suggests, has taken place in a number of markets. Notably, canned tuna has made gains against canned salmon, and haddock and ocean perch against cod in the ground-fish market. The change in the salmon-tuna relationship over the years in the United States market (see Fig. 1) has been related to diminished salmon runs, greater promotional efforts by the tuna industry, and a very significant reversal of the price-relationship between the two products (47).

The gains made by other groundfish species at the expense of cod have been explained by the association of cod, in the mind of the consumer, with salted products which, with the development of freezing, have generally declined in the market. Also, with the spread of filleting, haddock and other species proved to be better suited to plant operations and this factor, too, is said to have affected the market for cod.

In Canada, cod has still another competitor in the market, aside from the above-mentioned species. The intensity of the halibut fishery, thus, it has been found, appears to be directly related to the ratio of halibut to cod prices.

Turning now to the luxury items, what are some of the factors accounting for the varied fortunes of some species which, in Taylor's words, are *sui generis*? Rising incomes undoubtedly are, to a large extent, responsible for the growing share of shellfish and molluscs in the total consumption of fishery products in North America (in the United States, they represent as much as 40 per cent of catches). Why, however, did the market for oysters shrink so greatly, while shrimp gained to the extent that the fishery today is the most valuable one in the United States?

Woodward blames the decline in the oyster industry partly on high cost production due to the inability of the fishery to mechanize operations. He also blames preoccupation with production problems, with a consequent neglect of promotional efforts (the latter attributable also to the individualistic character of oyster packing standing in the way of concerted sales promotion); a typhoid scare in the 1920's; a growing popularity of other "snack items" prepared from meat products; and competition from shrimp, crabmeat, and lobster. He adds that the above-cited factors, including those related to production problems, may not only have reduced the crop directly but that, as a result of lessened "market exposure" of oysters, they may also have had a fundamental influence on consumer habits, this being an example where demand may have been directly affected by supply availability (48).

The success story of shrimp is explained by Woodward, aside from the close parallel of rising demand to rising consumer incomes, by social and institutional changes which have greatly increased consumption outside the home (49) and to improvements in technology which have made high quality fresh or frozen shrimp widely available in consumer markets.

Shrimp is said to owe its popularity also to the fact that it can be served in a variety of dishes, ranging from appetizer, soup, and salad to entrée. A good flavour, convenient packaging, and promotional efforts stressing the high nutritive value of shrimp are also cited as factors encouraging consumption (50).

Consumer characteristics influencing demand

The basic unit in the analysis of consumer demand is the individual consumer or, at most, the individual family, household, or spending unit. Each family has certain characteristics which are important in relation to its expenditure pattern and to its food habits and preferences.

Consumer characteristics are associated with national origin, race, religion, income, financial commitments, and initial patterns of expenditures; number of persons in the family, their ages and sex; occupation, age, and education of the household head and the homemaker, and outside employment of the latter.

Two large-scale consumer expenditure surveys undertaken in the 1950's in the United States (51) both concluded that there was a high degree of uniformity in spending habits in the large class of middle-income families which extended to practically everything families bought except food.

In the kitchen, traditional habits apparently carry considerable weight: the desire to "keep up with the Joneses" is less compelling than in other phases of daily life in the United States. MacKenzie finds "the fish-eating segment of the population in North America is composed largely of (a) European settlers of the first generation and their immediate descendants, (b) migrants from the Atlantic States and provinces and from other coastal or lakeshore areas, and (c) certain other groups perhaps, with an acquired taste for fish as a food. Between 75 and 90 per cent of consumer-respondents in surveys report having been served fish in childhood. The implication is that, like food preferences in general, those for fish tend to follow habitual patterns. Evidently, also, impulse buying plays an insignificant rôle in family expenditure on fish products" (52).

Other peculiar aspects of demand revealed by consumer surveys are that religious observance has an important influence on fish consumption. Consumption in areas with large Roman Catholic populations tends to be above average during Lent and on Fridays. Jewish people have a traditional preference for fresh-water fish. Other groups, in part at least for economic reasons (e.g. Negroes in low-income areas, as already pointed out) consume relatively large quantities of fish. The same surveys, however, provide an indication now and then that traditional group patterns tend to disappear in the melting pot of North America and, more generally, that preferences change over time.

To cite an example from the previously referred to survey of canned fish and shellfish preferences, homemakers in the younger age group are primarily responsible for the growth in canned tuna sales, whereas canned salmon is still favoured by the older generation (53).

The younger consumer, too, places greater emphasis on ease in preparation and convenience in shopping, handling in the home and serving. Increased employment of the homemaker outside the home, the general tendency to mechanize household operations, have fostered the expansion of filleting, the introduction of pre-cooked products in the market, the preparation of packaged seafood dinners, etc.

High quality and regularity of supplies in the market are other requirements increasingly stressed by consumers contacted in consumer preference surveys.

To a large extent, the high premium placed on convenience and quality reflects the postwar improvement in incomes. To summarize the findings of various studies, rising incomes have produced a shift to high-value species, have spurred sales of more expensively processed and packaged products, and encouraged provision of additional marketing services and, in particular, brought about an increase in restaurant consumption of fish. Rising incomes, at the same time, appear to be pushing some inferior products with negative income elasticity out of the market.

Clues on the income elasticity of expenditures for fish in the United States once more come from the 1948 and 1955 household consumption surveys. Appendix V shows that in 1955 average weekly household expenditures for high unit value shellfish were over four times as large for consumers with incomes of $10,000 and over as for consumers in the $1,000–$1,999 income class. Average expenditures for fish, in contrast, were only two and a half times as large. The difference in the demand for fish and shellfish, respectively, by different income classes is even more clearly shown when the comparison is made in physical terms. In 1955, thus, households in the highest income class bought over three and a half times as much shellfish in a week than those in the lowest income class. Average purchases of fish of high income households, on the other hand, were actually smaller than those of the households at the bottom of the scale. Income elasticity of expenditure for canned tuna was substantially greater than for canned salmon, the same tabulation reveals.

Comparing the results of the 1948 and 1955 surveys (see Appendix VI) one finds, thus, as far as fish is concerned, that there was comparatively little change in elasticity, as measured by weekly household expenditures. On the other other hand, shellfish which virtually were not bought at all by the low-income consumer in 1948 did become a component of his diet by 1955, expenditures in the latter year not differing substantially from those for canned salmon or canned tuna (see Appendix V). The data for shellfish also demonstrate that income elasticity of expenditure has a tendency to decrease, with income levels in the period from 1948 to 1955 having risen both in absolute and in real terms (in 1948 the ratio of average household expenditures on shellfish in the highest income class to those in the lowest income class was nearly 8 times as large as in 1955).

The future demand for fishery products

The total demand for fishery products for human consumption in North America will be a function, in the first place, of population growth. While population is the only determinant about which it is safe to predict in what direction it will influence demand, techniques for reliable population forecasts have not yet been developed. This is because nobody has been able as yet to devise a satisfactory theory explaining population growth in low-food-drain countries, such as most countries of the West are. In high-food-drain countries, in contrast, it has been pointed out, the Ricardo-Malthus-Mill theory is still of relevance (54).

As far as North America is concerned, raising the population scare does not make much sense, as Schultz points out, since it is fallacious to relate the food supply on the continent to the population of the world as a whole. In selection and construction of relevant aggregates for future needs, the "separation of the food of one population from the food of another is a fundamental consideration" (55). Under the circumstances, no convincing case in favour of an expansion of fisheries in the interest of developing food supplies for increased population on the continent can be made, at least not as far as the next few decades are concerned.

Only to maintain present per capita consumption rates the United States, however, will have to increase in all probability both domestic production and imports. With population by 1975, according to one projection, estimated to exceed 230 million, fish and shellfish supplies will have to be at least 1·3 billion pounds larger to meet consumer requirements. In his message on national resources to Congress on 23 February, 1961, President Kennedy actually put additional fish and shellfish requirements for the year 1980 considerably higher, viz. at 3 billion pounds. The latter figure, however, was meant to include needs for industrial purposes.

Per capita consumption may, of course, change in the long run, making necessary a revision of total supply needs. This may come about partly as the result of a change in size of what MacKenzie calls the "fish-eating segment of the population", and partly as the result of a change in the average amount of fish eaten by those who belong to this segment.

In the long run the demand for fish is considerably more elastic than in the short run, the experts agree. Primarily, this is because in time consumer habits and preferences can be influenced by purposive action of the trade. Conversely, if promotion is neglected, competitive products are likely to reap the benefits of market expansion. Borgström, in this connection, cites statistics relating to the year 1957, which appear to indicate that seafood promotion in the United States is small compared to sales efforts in other sectors of the food field (56). To be successful, promotional activities must, of course, take into account existing trends in consumer habits and preferences, in incomes, and in the distribution and composition of the population.

In general, such factors as a continued shift of population to the West coast (consumption on the coast still being larger than inland), an increase in the proportion of young people (more aware of nutritional factors, as a rule, than older people), increased employment of homemakers (with many fishery products well adaptable to processing and preparation for ready consumption) a continued upward trend in incomes, may all contribute toward raising per capita consumption.

It has been demonstrated that fish has a number of close substitutes in the North American market. Thus, to add a word of caution, prices of fish relative to prices of these products must not be allowed to get out of line, if consumption is not to be adversely affected. In this connection, Cassady points out there is reasonable ground for hypothesizing "that if prices changed in the United States to favour meat as compared with fish . . . there would be a strong tendency toward increased meat consumption at the expense of fish, other things being equal. However, assuming our hypothesis is correct, the tendency would not be nearly as strong if price changes favoured fish as compared with meat . . ." (57).

Relative prices are determined to a large extent by costs of production in the various fisheries, by trade policies, and by the character of the internal organization of the industry. Public action shapes trade policies, and internal organization can only be affected by concerted industry action or by the Government, e.g. through anti-trust procedures. Action on costs, on the other hand, can be taken by the individual member of the industry, although supply elasticities in the individual fisheries will influence average levels of costs.

In this connection, reviewing underlying trends in consumption and production of Canada in the recent past, MacKenzie finds that at present the products of the fisheries fall into three broad classes (58):

(A) Products with static declining demand,
  (1) cured fish;
(B) Products with growing demand and (relatively) inelastic supply,
  (1) fresh and frozen dressed fish,
    (i) lobster,
    (ii) salmon and halibut,
    (iii) major freshwater species;
  (2) canned salmon;
(C) Products with growing demand and elastic supply,
  (1) fresh and frozen fillets of ground fish,
  (2) canned herring.

MacKenzie mentions, in addition, unexploited or lightly exploited resources (e.g. Pacific saury and Atlantic mackerel), for which no significant demand exists at the present time.

He concludes that, as far as the Canadian fisheries are concerned, demand for all of the products, except perhaps cured codfish and one or two other products, may be expected to increase. This means that prices of the products listed under (B) will, in all probability, continue to rise, a factor that should not be forgotten in evaluating market prospects.

Development of new industrial uses for fishery products may, of course, wean supplies away from human consumption. As long as supply gaps can be readily made up by imports from abroad, though, there appears to be little danger that the consumer on the North American continent will be forced to curtail his consumption of fish and shellfish, because domestic fisheries are not in a position to meet his needs.

On the other hand, as pointed out by Anderson (59), a drastic upward change in per capita consumption rates of fishery products within the next few decades does not appear to be in the offing.

PART IV. THE DEMAND FOR FISH IN DEVELOPING COUNTRIES

Average daily consumption of animal protein ranges from 8–15 g. in developing countries as against 42–70 g. in industrialized countries. These statistics illustrate in part how far behind the former countries are in meeting the dietary requirements of their populations.

With the emphasis on urgent social needs rather than on individual desires and preferences, comparatively little has been done to date in developing countries in exploring the nature of the demand for fishery products. Fishery programs have been dominated for many years by the effort to increase production in accordance with certain nutritional targets. Recently, however, it has been increasingly recognized that, if development is to take place on a balanced basis, efforts in the production field must be paralleled by action in the sphere of marketing.

Specifically, these efforts must be directed toward improving the distribution system and toward mobilizing demand through appropriate educational measures.

After the products have been brought to the local market, and the public has been introduced to them through promotional campaigns, success in reaching established targets will still remain partial until consumers have sufficient income to be able to buy them. Improvement in purchasing power, however, depends on the rate of general economic development and is a matter of the long run.

A high priority has been given to means of increasing the availability of fishery products in the market. For this purpose, roads are required and appropriate means of transport, storage, and distribution have to be acquired or built, and an efficient marketing organization created.

In the field of consumer education, the first step is to familiarize potential buyers with fishery products. In the long run, the program must aim toward breaking down patterns which discourage consumption of fish and which may be traceable to national traditions or religious taboos.

Efforts along these lines have been initiated in most developing countries. To date they have been successful in varying degree, depending on the scope of programs, skill of direction provided, and the extent of co-operation given by the people themselves.

Systematic surveys of demand conditions in developing countries have been undertaken only in rare instances. Observations on factors influencing the market for fishery products, however, have been included in a good many of the reports on FAO technical assistance assignments. These reports, therefore, present interesting clues on what factors appear to be hampering the expansion of the market for fishery products and on what positive action can be taken to overcome these obstacles. Relevant excerpts are summarized in the following sections.

Availability and other factors related to market supplies

Lack of supplies, that is continuous supplies, in the market is a much more important determinant of demand in developing countries than in industrialized countries, and has seriously impeded the formation of fish-eating habits.

The reasons why the populations of developing countries do not find their markets adequately supplied with fishery products run the entire gamut of factors from catching, transport, storage, processing, and distributing operations to ultimate sale. They relate not only to adequacy of facilities and efficiency of methods, but also to institutional aspects such as the organization of marketing.

Discussion of technological factors affecting supply availability is outside the realm of this paper. Lack of facilities, suffice it to say, is frequently related to economics. Construction of roads and provision of transport and storage facilities exclusively to serve fisheries can rarely be justified in terms of net economic benefits. This is partly because of the small volume and value of the products involved, partly because of the nature of some markets, where (as in Libya and in other Near Eastern countries, for instance) low population density contributes toward making distribution costs excessively high.

Climatic conditions, too, make it necessary to use facilities, methods, and processes which do not provide for utilization along lines which are most advantageous from an economic standpoint.

In a surprising number of instances, defects in the marketing structure are the major bottleneck in distribution. Inefficiency in the organizational set-up and collusion among marketing agents are frequently responsible for withholding supplies from the market and for raising prices to levels which curtail consumer purchases. In some instances (again Libya can be cited as an example) collusion starts at the fishermen's level. Lack of supplies at the markets in the principal population centres of the country at certain times has been related to the practice of the fishermen to restrict their fishing to a level which ensures high prices.

In India and other countries of the Far East, similar restrictive practices are encountered in the marketing sector, i.e. under the widely prevalent middlemen system. This system tends to maintain fish supplies at artificially low levels in the interest of reduced risks and high profit margins. It owes its continued existence, in part, to the fact that middlemen provide certain facilities and services (in the form of transport, equipment and financial aid) to the fishermen; the latter, in the face of adverse climatic, geographic, and social conditions, are unable to provide these for themselves.

In Africa, control of retailing by the "mammies", the market women, each of whom handles the catch of one boat only, has made retailing very costly. The volume handled is small and the overhead, consequently, rather high. Attempts to institute market reforms have, in many instances, been thwarted through concerted action by the market women. Thus in Stanleyville, the buying public has been persuaded to boycott newly established Government-supervised shops. In Sierra Leone, pressure on the authorities has resulted in a legal injunction against direct selling by fishermen.

The ability on the part of the market women to persist in simultaneously maintaining technically poor methods of trading, small individual turnovers, and relatively high incomes can be traced, according to one expert, to the fact that the women are selling the product of fishermen who have extremely weak bargaining power, and to the additional circumstance that there is no substantial competitive pressure from other foodstuffs which might depress the margins they realize.

One more example from tropical Africa may be cited to demonstrate how traditions, by now extinct, have created an extremely complicated and inefficient marketing apparatus. In the Republic of Mali, fish goes through the hands of a chain of middlemen (called "coaxers") who enter into the picture at various stages of processing, handling, retailing, etc. The system goes back to old taboos under which families or chiefs and warriors were forbidden from engaging in commercial activities. Such activities were, consequently, entrusted to special agents, the "coaxers". While the taboos no longer exist today, the system survives and perpetuates uneconomic operations in the trade.

The quality of market supplies has a bearing on the demand for fish in developing countries as it has in industrialized countries. However, concepts of quality frequently are materially different. African buyers of fish in some areas, thus, are reported to be relatively little concerned about insect infestation and actually prefer tastes and flavours which would be considered unacceptable in most developed countries. Where the African, however, is in closer contact with Europeans, such as in the larger cities, a higher-quality product will frequently be demanded. This may be a consequence, in part, of the higher incomes which are earned in these areas.

Related to the quality problem are certain institutional factors such as unsatisfactory hygienic conditions in retail establishments, unattractive display of products, bad merchandizing, etc. These factors have been found to be detrimental to sales of fishery products in urban centres in such countries as Brazil and India, where more advanced types of facilities exist.

Price and income factors

High prices of fishery products frequently are mentioned as the principal reason for discouraging consumption of fishery products in developing countries. It is true that prices often are actually higher than they would be if market competition were given free rein and if standards of efficiency were on a more elevated plane. Perhaps equally often, however, complaints about high prices merely reflect a lack of purchasing power which prevents consumers from enriching their diets with the addition of more expensive animal protein products. From a nutritional standpoint, the most tragic fact is that those whose diets are the poorest are often those least able to afford to buy fish and other animal protein products.

Available statistics bearing on the relationship of expenditure to income are too scanty to warrant detailed analysis. Crutchfield, however, in the course of a survey in Uganda a few years ago, was able to review results of two studies relating to unskilled African workers in the Kampala district carried out by the East African Statistical Department in 1953 and 1957. The data indicate that expenditures for fish rose steadily through the range of incomes covered, both in absolute terms, and as percentages of total food expenditures. Purchases of meat, in contrast, tended to taper off at the upper limit of the range. Crutchfield cautions that the effect of a general increase in all incomes may be different from an increase in the income of one spending unit relative to others in a given distribution. Also, the study he cites covers only a certain group of employed workers. Nevertheless, he feels that the results provide some support for the conclusion that per capita fish consumption will respond positively and strongly to long-run increases in real incomes (60).

Because of differences in dietary habits, Crutchfield says, the competitive relationships between fish and other foods differ from those in developed economies. All food products, thus, are substitutable for fish (and meat) to a much greater degree than in developed countries. The high sensitivity of demand to income is accentuated by the ease with which basic staples (Crutchfield mentions bananas, maize and cassava) can be grown, and by the lack of knowledge about the effects of protein deficiency.

In Uganda, to illustrate how patterns differ from those in Europe and North America, poultry and eggs are relatively unimportant in total consumption, and only a portion of the amount consumed actually enters marketing channels. The principal competitive protein foods are beef and goat meat and, to a lesser extent, ground-nuts.

"From the standpoint of fish marketing", according to Crutchfield, "it is evident that the availability and prices of meat exert much less influence on the demand for fish than in most Western economies. Meat constitutes a relatively smaller and much more stable element in the food supply of Uganda, and the consumer taste for fish is much stronger. Variations in income are a far more important determinant of demand for both fish and meat than changes in their relative prices."

In some other developing countries, demand conditions appear to differ considerably from those found in Uganda. For instance, a recent survey shows that Moroccans, especially those in the lower income classes, prefer to buy, for a given amount of money, a reduced ration of meat rather than a full ration of fish. Elsewhere in the Near East, factors other than preferences also appear to enter the picture. In Libya, for instance, meat has an advantage in the market, insofar as cattle can be transported on the hoof; the distribution of fish to widely-dispersed communities, under prevailing climatic conditions, on the other hand, is costly, and presents special technical problems.

Consumer habits and preferences

The consensus of experts trying to evaluate the relative importance of various demand determinants for fishery products in developing countries is that availability and price and income factors have been of considerably greater importance to date than consumer habits and preferences, and relationships to competitive food products. This is in spite of the great emphasis that is given to taboos, and similar restrictions on consumption, found in the literature.

Statistical confirmation, of course, is difficult to obtain. For one thing, statistical services are frequently still in their infancy in developing countries. Furthermore, however, even if data collection were on a more advanced scale, obtaining a reasonable approximation of consumption levels would still be hampered by the circumstance that in many areas the fishermen themselves consume an appreciable portion of their catches, and customarily dispose of most of the remainder by barter.

Consumption of fish in developing countries, of course, could be expected to expand substantially if people not used to eating fish (because of unfamiliarity with the products, ignorance of their nutritional value, or because consumption is subject to a taboo) were to acquire the habit of including fishery products in their diets. Rigid preferences for certain species and certain forms, with discrimination, at the same time, against other species and other forms, too, it should be added, have had a depressing effect on levels of demand.

Taboos related to fish consumption are known to exist in most parts of the world. Generally they are not widespread; sometimes they are related to religious observance. They are found most frequently among groups somewhat remote from centres of civilization, and show a tendency to disappear upon increased contact with more advanced communities. They also tend to vanish when fish is available on a continuous basis, and where superstitions, consequently, are less likely to survive. Among the taboos which have been noted by technical assistance experts are the following:

The Chinese population of Malaya rejects talang, "queen fish", because this fish has five dots on each side which are believed to be the finger marks of Buddha. Vegetarianism in India, too, is related to religious factors.

In other countries, taboos are frequently connected with health superstitions. In Africa, thus, some tribal taboos are related to fears that fish will cause abortion and sterility among women. Some species, the Africans believe, will cause skin diseases. For the same reason, many Indians in Malaya reject shellfish.

Tilapia in some areas of southeast Asia is not fed to hogs, to cite another "fish superstition", because it has a dark skin. Farmers operating fish ponds are afraid that, if hogs were fed tilapia, their flesh would tend to become dark, and would be discounted in the market.

Appearance will influence consumption also in other ways. In Syria, for example, catfish cannot be sold in the round as are other fish, because buyers are repelled by the ugliness of the head of the species (on the other hand, the intestines are as a rule left in the fish, since there is a general belief that gutted fish is not fresh).

Doubts about quality also affect the consumption of frozen fish. These appear to be, in some instances at least, based on unfavourable personal experiences dating back to the time when the quality of the first frozen products introduced in the market was relatively poor. African consumers in Uganda, it is reported, are unwilling to buy frozen fish, even when fresh fish are scarce and of dubious quality. The usual explanations offered are, in the first place, that only "bad" fish are frozen; secondly, that frozen fish spoil very quickly; and thirdly, that the African buyer does not like "hard" fish, since he cannot judge its quality in the familiar way.

Certain characteristic food habits appear to have their origin in notions about nutritional needs. In Malaya, for example, salt fish is given to young mothers for several months after delivery.

A preference for salt fish exists in many of the countries with a humid tropical climate, where perspiration losses make additional salt intake necessary. Salted, dried fish products, for example, are used widely throughout southeast Asia, e.g. in Thailand, where this industry has a tradition of long standing. "Nam pla", a fermented fish sauce which is practically saturated with salt, is one of the most universally used food ingredients in the country.

In other countries with similar climatic conditions, however, non-salted fish is preferred, and salt fish may even be rejected outright. Thus in Ghana, in Nigeria, and among the Bantu in the Congo, there is virtually no demand for salt fish, and it is often difficult to make consumers accept an even slightly salted product.

Smoked fish is highly popular almost everywhere in Africa, and will command premium prices; even though products, because of the use of unsatisfactory processing techniques, are often of inferior quality.

Strong flavours are frequently preferred. Strongly-flavoured dried fish is often used to make less tasty food more palatable. The demand for it, therefore, one expert concludes, is not likely to be transferred to fresh, frozen, or canned fish, as the supplies of the latter will increase.

Other preferences encountered in developing countries relate to size, fat content, texture, and other physical characteristics of the fish. While large fish are generally preferred to small fish, and consequently fetch better prices in the market, small fish are better liked in Indonesia and are popular also in Malaya. The entire fish, as a rule, is eaten. In Tunisia, the Government is trying to encourage consumption of small fish. The policy, however, is dictated by the nature of the resources exploited, in which small fish predominate.

Fatty fish (for example, catfish) are highly appreciated throughout Africa, whereas bony fish, in many instances, are rejected.

The Chinese population of Malaya is said to prefer scaly fish, although almost all types and varieties of fish are accepted.

In many countries, seafish are liked better than sweet-water fish. The reverse is true in other countries (e.g. in the Congo and in Northern Nigeria) where the population has had little opportunity to get to know salt-water species.

Outlook

Population growth in developed countries, the discussion of the demand for fish in Western Europe and North America appears to indicate, may possibly lead to changes in consumption patterns (as a result of concurrent changes in income levels and in relative prices of fish and competitive foods). In developing countries, population growth will have more serious consequences. Even if the rate of population increase only remains the same as now, food needs can be expected to increase steadily, since food-producing capacity is not, in most areas, growing at a similar pace.

The problem of expanding supplies and of ensuring that food produced is brought to the market and purchased by the consumer, consequently, will become more pressing with time. Man's knowledge and ingenuity, therefore, must be applied to finding solutions, unless the dire conclusions of Malthusian thinking are to become applicable in the major part of this world.

One way of moving in the right direction, and accomplishing something immediately, is to overcome obstacles preventing the best utilization of already existing resources. These obstacles, the preceding has shown, partly lie in nature—distances between production and consumption centres, climatic conditions, etc.—partly in man—lack of knowledge of needs and opportunities, the thirst for monopoly profits, etc.

In a general way, the steps that must be taken were outlined at the beginning of Part IV of this paper. A few concrete examples of the activities that have been initiated by governments, with the help of international and bi-lateral assistance, along these lines in the fisheries field are listed in the following:

1. Road construction programs have been examined to determine whether, through comparatively small modifications of existing plans (e.g. by incorporation of connecting links to heretofore isolated landing points), the needs of fisheries could be served.
2. Marketing schemes aimed at increasing the level of trade and consumption in specific areas were set up. Drawing up plans for these schemes involved the selection of appropriate means of transport and facilities for preservation with ice as well as for storage and of the most economic methods of operation—considering production and market capacity, costs, and purchasing power of potential consumers.
3. Government-operated or supervised wholesale and/or retail market facilities have been installed to make supplies available on a more regular basis, to counteract restrictive practices and reduce prices, to improve quality and hygienic standards, etc.
4. Co-operative endeavours in production and marketing have been encouraged, and efforts have been made to wrest monopoly powers from middlemen, while at the same time letting them continue in those functions in the distribution system, which, by virtue of their experience, they are best qualified to exercise.
5. Market research has been expanded: products best suited to fill nutritional needs and, at the same time, most likely to find consumer acceptance, because of price and preference factors, are being developed and introduced.
6. Consumer education is being emphasized, and information on the dietary value of fish is being disseminated through lectures and demonstrations in schools and at public gatherings of all kinds. Systematic promotional campaigns to boost the consumption of fish have been started in a number of countries, preliminary results in most instances being very satisfactory.
7. Opportunities for increasing demand through expansion of institutional consumption are being investigated.

The foregoing is not an exhaustive list of the possibilities for taking action to raise the demand for fishery products in developing countries. The examples are merely given to show how much can be done, on a local basis and in specific sectors, pending an increase in the standard of living and in consumer purchasing power in these countries, which would bring about a general improvement in diets and which, in many countries, would undoubtedly lead to vastly increased consumption of fishery products.

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(14) Appendix II gives the various co-efficients which were found to exist.
(15) *Domestic Food Consumption and Expenditure:* 1955. Ministry of Agriculture, Fisheries and Food. H.M.S.O., London.
(16) *Fish Marketing in Western Europe Since 1950*, *op. cit.*, 59.
(17) *Ibid.*, 58.
(18) Unpublished study carried out for the White Fish Authority during June 1960. It might be contended that the approach employed—namely, to put statements to the interviewers and ask them if they agreed or not—carried a bias; but, inasmuch as consumer attitude surveys relating to fishery products are rather rare, the results are of some interest. The form in which the question was put to respondents is given here and also wherever else reference is made to the study.
(19) *Fish Marketing in Western Europe Since 1950*, *op. cit.*
(20) *Ibid.*, 131.
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(22) *Consumer Education in Food and Agricultural Products.* Project No. 308. European Productivity Agency, O.E.E.C., Paris 1959.
(23) *Fish Marketing in Western Europe Since 1950*, *op. cit.*, 149-150.
(24) Unpublished study carried out for the White Fish Authority during June 1960, *op. cit.*

(25) According to preliminary data, per capita consumption in 1960—in edible weight quantities—was 13·2 lb. in Canada and 10·5 lb. in the United States.

(26) In 1959, actually, more fish was taken for industrial than for consumption purposes.

(27) BORGSTRÖM, G., *op. cit.*, 227.

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(31) Based on surveys conducted by the United States Department of Agriculture. Data refer to 1 week in the period from April to June and to all urbanizations.

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(52) Unpublished draft by W. C. MACKENZIE, *op. cit.*

(53) *Canned Fish and Shellfish Preferences of Household Consumers*, 1956, *op. cit.*

(54) FOX, K. A., *op. cit.*

(55) SCHULTZ, Th. W., *op. cit.*

(56) BORGSTRÖM, G., *op. cit.*, 251.

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Appendix I. Average per capita fish consumption by countries

Country	*Weight basis*	*1938*	*1948*	*1958*
Western Europe				
Austria	Product weight	1·5	2·3	3·1
Belgium	Product weight	12·0	13·2	12·6
Denmark	Whole fresh weight	10·0	15·0	12·0
France	Product weight	9·3	9·1	11·9
Germany (F.R.)[1]	Whole fresh weight	11·8	15·4	11·4
Germany	Fillet weight	6·8	9·1	6·5
Greece	Product weight	6·6	—	12·1
Iceland[2]	Landed weight	(90·0)	(95·0)	(100·0)
Ireland	Product weight	5·7	5·0	6·4
Italy[3]	Product weight	6·7	4·4	7·9
Netherlands[4]	Edible weight	5·7	7·2	4·8
Netherlands	Whole fresh weight	9·9	12·7	8·9
Norway	Landed weight	—	—	41·0
Norway	Whole fresh weight	—	—	52·0
Portugal	Product weight	28·0	25·7	32·1
Spain	Landed weight	—	17·5	19·7
Sweden[5]	Product weight	17·4	17·1	17·6
Switzerland[6]	Product weight	1·5	—	3·0
Turkey	Product weight	1·0	1·0	3·5
United Kingdom	Edible weight	11·8	14·1	10·3
Yugoslavia	Whole fresh weight	—	—	1·0
North America				
Canada	Edible weight	5·2	5·8	6·1
United States	Edible weight	5·0	5·0	4·7

[1] The figures for 1938 refer to 1934-38.
[2] The figures given represent estimates based on fish consumption in the capital.
[3] For 1938 and 1948, molluscs and crustaceans are excluded.
[4] The figures for 1938 and 1948 are estimates.
[5] The figures for 1938 refer to 1939 and for 1958 are preliminary.
[6] The figures for 1958 refer to 1957 and the figures for 1938 refer to 1940.

Source: Fisheries Policies in Western Europe and North America, OEEC, 1960, Table 38.

Appendix II. Estimates of income and price elasticities of demand for individual foods

	Income elasticity					
	1955		*1958*			
	Quantity purchased	*Expenditure*	*Quantity purchased*	*Expenditure*	*Price elasticity*	*Seasonal or annual shifts in demand*
FISH:						
White, fresh	0·20	0·36	0·21	0·36	– 1·17 (0·20)	S
Herrings, fresh	0·03	0·07	0·21	0·24	– 1·64 (0·44)	S
Fat, fresh, other	0·55	0·99	0·50	0·34	– 0·61 (0·18)	S
White, processed	0·62	0·64	0·66	0·73	– 1·30 (0·46)	S
Fat, processed	0·25	0·31	0·39	0·54	- 0·11 (0·39)	S, A
Shell	0·86	1·18	1·15	1·14	n.a.	
Cooked	– 0·19	- 0·18	– 0·19	– 0·04	– 1·20 (0·46)	S, A
Canned and bottled	0·60	0·63	0·43	0·63	+ 1·17 (0·28)	A
Fish products	0·14	0·40	0·04	0·17	n.a.	
Total fish	0·23	0·38	0·20	0·41		

Appendix III. Income-expenditure elasticities for fish products and some related demand elasticities

Survey	*Elasticity co-efficient Expenditure*	*Demand*	*Standard deviation (Exp.)*	*Coverage of survey*
1. Austria 1954–55	·77*		·07	Cities over 10,000 pop.
11. Egypt 1955	1·13		·03	Three villages
12. Finland 1950–51	·54	·22	·05	Wage earners, 18 cities
16. France 1951	·74*		·06	17 cities over 100,000 pop.
18. Germany 1950–51	·51	·24	·08	Cities over 5,000 pop.
20. Germany 1953	·87		·10	Farmers
25. Ghana 1954–55	·72*		·09	Three cities
26. Greece 1957–58	·80			Urban
28. India 1951–53	1·16*			Rural
29. India 1951–53	1·11*		·03	Urban
32. Ireland 1951–52	·94*	·66*	·04	All population
35. Italy 1953	·75*		·04	All population
36. Italy 1953	1·04*		·13	Farm families—South
37. Italy 1953	·79*		·11	Farm families—N. central
38. Italy 1953	·90*		·08	Non-farm families South
39. Italy 1953	·60*		·06	Non-farm families North
40. Italy 1953–54	·50*	·18*	·04	Non-farm pop.
42. Japan 1951–52	1·02*		·06	Farm pop.
44. Japan 1953–56	·51*[1]		·01[1]	Urban workers
46. Japan 1955–56	1·15*		·06	Farm pop.
47. Netherlands 1951	·37	·47	·04	All pop., excl. farmers
52. Panama 1952–53	·17*		·10	Panama City
53. Philippines 1954	·56*		·17	Manila and suburbs
54. Portugal 1950–51	·67*		·10	Porto (mainly urban)
55. Puerto Rico 1952	·20*		·04	Wage earners
56. South Africa 1955	·76*		·02	Urban white families
62. United Kingdom 1953–54	·38		·06	All population
65. U.S.A. 1955	·27*	·00*	·07	All population

* A correction factor + ·12d has been applied to take into account the size of the household.

[1] Elasticity of fresh fish: ·52* (·02).

Source: Unpublished survey prepared by Mr. L. M. Goreux, FAO.

Appendix IV. Changes in composition of United States catches
1889–92 to 1960

(*Selected years and food-fish species*)
(in *1,000* lbs.)

	1889–92 composite	*1908*	*1929–31 average*	*1938–40 average*	*1960*
Oysters	169,293	148,872	82,791	80,092	57,700
Cod	163,912	102,107	103,864	109,474	45,000
Haddock	49,957	59,987	237,112	163,106	118,600
Flounders	10,363	23,346	71,968	85,506	130,300
Shrimp	8,225	19,080	101,674	148,784	248,700
Tuna	—	—	76,066	170,868	296,900

Data in first four columns from H. F. Taylor, Survey of Marine Fisheries of North Carolina, pp. 407–409—The University of North Carolina Press, Chapel Hill, 1951.

Data for 1960 from Fisheries of the United States, 1960 (A Preliminary Review) by E. A. Power, F. L. 393, Washington, D.C.—April, 1961.

Appendix V. Weekly household consumption in the United States

Purchases of fish and shellfish products in the spring of 1955, *by income groups*

Income Groups	*Total fish*	*Total Shellfish*	*Canned Salmon*	*Canned Tuna*
Quantity purchased per household (lbs.)				
1,000–1,999	1·09	·11	·16	·05
2,000–2,999	1·37	·13	·13	·08
3,000–3,999	1·21	·19	·13	·14
4,000–4,999	1·14	·20	·10	·17
5,000–5,999	1·09	·23	·14	·15
6,000–7,999	1·46	·27	·13	·17
8,000–9,999	1·01	·13	·17	·20
10,000 and over	1·06	·39	·12	·20
Money value of purchases per household ($)				
1,000–1,999	·37	·08	·09	·04
2,000–2,999	·46	·08	·08	·06
3,000–3,999	·52	·10	·08	·11
4,000–4,999	·54	·17	·07	·13
5,000–5,999	·60	·19	·09	·14
6,000–7,999	·74	·23	·09	·14
8,000–9,999	·67	·12	·11	·16
10,000 and over	·93	·35	·09	·17

Based on surveys conducted by the U.S. Department of Agriculture. Data refer to 1 week in the period from April to June and to all urbanizations.

Appendix VI. Weekly household consumption in the United States

Expenditures for fish and shellfish products, comparison between 1948 and 1955, by income groups

Money income after income taxes for households of 2 or more persons ($)	*Fish*		*Shellfish*	
	1948	*1955*	*1948*	*1955*
Money value of purchases per household ($)				
1,000–1,999	·38	·37	·005	·08
2,000–2,999	·45	·46	·03	·08
3,000–3,999	·50	·52	·06	·10
4,000–4,999	·59	·54	·07	·17
5,000–7,499 (1948)	·60		·12	
7,500 and over (1948)	·84		·17	
5,000–5,999 (1955)		·60		·19
6,000–7,999 (1955)		·74		·23
8,000–9,999 (1955)		·67		·12
10,000 and over (1955)		·93		·35

Based on surveys conducted by the U.S. Department of Agriculture. Data refer to 1 week in the period from April to June and to all urbanizations.

Fish is the main source of animal protein in the popular diet of the Congo where the Potopoto market in Leopoldville is here illustrated. To cope with the famine threat in that country the FAO took prompt steps amongst which was a survey by a marketing expert to improve the distribution methods of all foods but particularly of fish because of the strong demand for it as a human food.

GENERAL INTRODUCTION

FISH FLOUR*

La farine alimentaire de poisson
Harina de pescado

TECHNOLOGICAL DEVELOPMENTS IN CANADA, ICELAND, SCANDINAVIA, SOUTH AFRICA AND THE UNITED STATES OF AMERICA

Développements technologiques au Canada, en Islande, dans les Pays Scandinaves,
en Afrique du Sud et aux Etats-Unis d'Amérique
Adelantos técnicos en Canadá, en Islandia, en los Paises Escandinavos, en
Sudáfrica y en los Estados Unidos de América

This report contains condensed versions of five country statements prepared for the Conference by H. Fougère (Canada); Gudlaugur Hannesson (Iceland); Kaare Bakken (Norway); G. M. Dreosti (Republic of South Africa); and E. R. Pariser (United States of America). Editorial comments have not been included and wherever possible the original nature, context and structure of the material prepared by the original authors has been retained. In a few instances, however, material not included in the country statements has been added to aid in the continuity, interest and clarity of the report.—D. G. Snyder.

INTRODUCTION

MALNUTRITION is to a great extent the result of an inadequate consumption of high quality protein which is needed to complete and to balance the diets of peoples whose food contains preponderantly vegetables and cereals. Sadly enough, young growing children and expectant mothers suffer most from a lack of proteins containing sufficient quantities and correct proportions of the required amino acids. Milk, eggs, meat, fish and chicken all contain high quality animal protein but are often too costly and are not universally available. The need is great for a satisfactory, inexpensive animal protein of high quality which might be suitable for incorporation into the diets of peoples suffering from protein malnutrition.

Fish, although a staple diet of recognized nutritive value since man's early hunting days, has always been difficult to preserve and distribute. Moreover, in tropical and sub-tropical countries where inexpensive protein is needed most, the means of preservation, transportation and distribution are least available. Efforts to overcome these obstacles are by no means limited to modern day science. For instance, the Egyptians were intimately acquainted with the art of curing fish with salt and the Romans developed processes for the manufacture, from fish, of an enzyme-digested amino acid concentrate that was used as a universal seasoning.[1]

Only recently more systematic studies have been initiated to prepare a satisfactory, cheap, concentrated quality protein and mineral food supplement. Such a product, variously known as fish flour, edible fish meal or fish protein concentrate, is generally considered to be a dehydrated, partially or almost completely defatted product which may or may not be flavourless or odourless.

During the last few years, many processes have been studied for the manufacture of fish flour for human consumption in different countries. These studies indicate the possibility of producing, at low cost, a concentrate of high nutritive value and long shelf-life. Hundreds of tons of fish flour have been produced and consumed in Sweden, Morocco, and South Africa, but it is only now, thanks to the untiring efforts of International Agencies of the United Nations, that fish flour is receiving the attention it deserves as a weapon in the universal fight against hunger.

This report contains a general discussion of the problems encountered in the manufacture and use of fish flour, as well as a review of the technical endeavours to produce a satisfactory fish flour in Iceland, Canada, the United States, Republic of South Africa, and Scandinavia. Early efforts and problems, the processes and processing variables currently being studied, and the nature of the resultant products have been considered.

PROBLEMS ENCOUNTERED IN THE MANUFACTURE AND USE OF FISH FLOUR

Keeping qualities, consumer acceptance, cost, and nutritive quality of the product, as well as the flexibility and safety of the manufacturing methods used, are factors that need consideration by scientists contemplating development of a satisfactory process to produce an edible fish flour. These factors, which are interrelated and all of considerable importance, are examined briefly below so that the reader may have a better understanding of the complexity of the problems encountered.

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[1] B. Flower and E. Rosenbaum, Apicius, The Roman Cookery Book, Peter Nevill, Ltd., London and New York, 1958.

* The term "fish flour" was used throughout the documentation and discussions of the FAO International Conference on Fish in Nutrition and has, therefore, been retained in this publication. However, to avoid confusion with cereal flours, FAO, in consultation with a panel of experts, has decided to use the term "fish protein concentrates" to describe ground dried fish products intended for human consumption.

Keeping qualities

The manufacturing process used must result in a product that can be stored for long periods under tropical temperatures and under generally adverse conditions without loss of quality. The process, then, must be effective in removing most or all of the oil, the odiferous compounds and their precursors. To remove the oil, attention has turned largely to processes based on extraction of the raw or precooked fish with one or several solvents. Some of these seem to be effective.

Dehydration of the raw material is important to ensure adequate keeping qualities of the protein concentrate. Dehydration procedures also enter into considerations relating to processing costs and nutritive value of the finished product. For satisfactory storage the product should contain less than 10 per cent moisture to discourage growth of spoilage organisms. The methods of dehydration that have found application can generally be classified as wet reduction and dry rendering, vacuum drying, azeotropic distillation, and air drying.

Finally, great attention must be given to the overall sanitary aspects of the entire process, since poor handling and unsanitary working techniques will enhance the possibility of product deterioration.

Acceptance

The manufacturing method must result in a product that can easily be incorporated into the food of the potential consumer without lowering the appeal of the local dishes. Such factors as form, particle size, and grittiness of the end product are important. Tastes differ—some peoples prefer a distinct flavour, while others would object to any fish taste or odour. In the latter case, the flour has to be refined, deodorized, or manufactured in such a manner as to be flavourless and odourless.

Knowledge is necessary of the food in which the fish flour can be incorporated and also about the effect of such supplementation. For instance, supplementation of chocolate icing with a highly refined, deodorized fish flour, conducted at the College Park Laboratory of the Bureau of Commercial Fisheries in the United States, completely altered the characteristics of the icing.

Cost

Unless people who need the fish flour can afford to buy the product, the value of the efforts devoted to product development is largely lost. Cost considerations are, therefore, all-important. About one-fifth of the raw material weight is recovered as fish flour after removal of moisture and oil. Thus, the cost of the flour is more than five times that of the raw material since processing costs must also be included, although some saving results from lower shipping costs through decreased weight.

Aesthetic requirements, such as the use of only fillets, would further decrease yield to only $\frac{1}{12}$ to $\frac{1}{15}$ of the raw material weight, as well as adding to processing costs. Thus, the types and parts of fish used as the starting material are very important.

In some countries low initial capital outlay for the processing plant would be essential or else industry would be hesitant to enter into the venture. Too, the operation should be economical. Such matters as heat loss, solvent recovery, workman hours, equipment costs, and the like need attention.

Nutritive value

Whenever a raw material is processed, the nutritive value of the resultant processed food product may be altered and often reduced. In this connection it must be noted that fish flour is intended primarily as a dietary protein supplement. Therefore, the nutritive quality of the fish protein must be high to supplement the proteins of the basic diet. The possible loss of minerals during processing must also be considered, since some nutritional deficiencies involve limited mineral intake. Vitamin losses, although perhaps of lesser importance, should certainly be considered as well.

Thus, selection of a processing method must be based on its potential for yielding a uniform and nutritionally consistent product. Solvents and drying methods used, parts and types of fish, storage conditions, sanitation methods employed to prevent mould, bacteria, and insect infestation may all affect the nutritive value and wholesomeness of the resultant product. Solvents and solvent residues that may be harmful must be eliminated from the finished product.

Flexibility and safety in manufacture

If a wide market is envisaged, the manufacturing process must be flexible to permit the manufacture of a product that will be accepted by people of widely varying taste preferences and eating habits. The process should be flexible for large and small scale production to assure maximum utilization of our global fishery resources. If manufacture is to be considered in developing countries, it is especially important to consider the requirements of operations in localities where public utilities are limited. In all cases, safety considerations must be observed, especially when solvents are employed in the manufacturing process.

TECHNOLOGICAL DEVELOPMENTS IN CANADA

by

H. FOUGERE

Fish flour investigations in Canada were initiated at the Halifax Technological Station of the Fisheries Research Board of Canada in 1955. Two objectives were in sight: a product of high quality protein for human consumption and the efficient utilization of fish offal resulting from filleting plant operations.

Other countries as well have developed processes for manufacturing fish flour, the basic principle being the same, namely solvent extraction.

1. **The isopropanol process** involves:

(*a*) Acid treatment of offal with polyphosphoric acid at pH 5·5 to hydrolyse the collagens.

(*b*) Solvent extraction of the presscake.

2. **Studies of solvent extraction—experimental procedure and data.** Systematic investigations of the efficiency of acetone and isopropanol as solvents are reported, ethyl alcohol and trichlorethylene being also considered. It was subsequently observed that the acid treatment of offal presented the disadvantages of removing water soluble proteins and thus reduced the yield of the final product. Guttmann (Halifax) undertook to demonstrate this fact by presenting data on the loss of protein nitrogen as well as of the individual amino acids. Furthermore, this investigation led to a *simplified process*, giving a higher yield, and a *method for preserving* the raw material for subsequent processing.

3. **Nutritional.** It has been demonstrated that fish flour (isopropanol process) is equally as good as egg albumin and is nutritionally more complete than casein.

4. **Utilization.** Although fish flour is not manufactured commercially in Canada some home economists are experimenting with it by adding it to wheat flour in baking bread, biscuits and fortifying cereals. It was thought that cereal flours, of which Canada has yearly surpluses, when mixed with fish offal, might have some merit. One product in particular, 30 per cent protein, was obtained. It is easily prepared, dries easily, requires no solvent extraction and its taste and odour are quite acceptable. In addition, apple presscake, a by-product of the apple juice industry in Nova Scotia, when added to fish offal with vegetable flour has the property of masking fishy tastes and odours. A suggestion follows that dry pineapple presscake which should be abundant in countries close to those where the need for more protein is emphasized, could serve a similar useful purpose.

DEVELOPPEMENTS TECHNOLOGIQUES AU CANADA

Au Canada, des recherches sur la farine alimentaire de poisson ont été entreprises en 1955 à la Station technologique d'Halifax, du Fisheries Research Board of Canada. On visait deux objectifs: un produit d'une haute valeur en protéines pour la consommation humaine et l'utilisation efficace des déchets de poisson résultant des opérations dans les usines de filetage.

D'autres pays ont aussi développé des procédés pour la fabrication de farine de poisson sur les mêmes principes de base, c'est-à-dire l'extraction aux solvants.

1. **La méthode à l'isopropanol** comprend:

(*a*) le traitement à l'acide des déchets avec de l'acide polyphosphorique au pH 5,5 pour hydrolyser les collagènes.

(*b*) l'extraction au solvant du gâteau de presse.

2. **Etudes de l'extraction au solvant—méthode expérimentale et données.** Une recherche systématique sur l'efficacité de l'acétone et de l'isopropanol comme solvants a été effectuée, l'alcool éthylique et le trichloréthylène étant pris aussi en considération. On a observé par la suite que le traitement à l'acide des déchets présentait l'inconvénient d'enlever les protéines solubles dans l'eau, réduisant ainsi le rendement du produit final. Guttmann (Halifax) a entrepris de démontrer ce fait en présentant des données sur la perte de l'azote protéique ainsi que des acides aminés individuels. En outre, ces recherches ont abouti à un *procédé simplifié*, donnant un rendement plus élevé, et à une *méthode de préservation* de la matière brute pour un traitement ultérieur.

3. **Valeur nutritionnelle.** On a démontré que la farine alimentaire de poisson (méthode à l'isopropanol) est à égalité avec l'albumine de l'oeuf et, du point de vue nutritionnel, est plus complète que la caséine.

4. **Utilisation.** Bien que la farine alimentaire de poisson ne soit pas fabriquée industriellement au Canada, des spécialistes de l'économie domestique procèdent actuellement à des expériences en l'incorporant à de la farine de blé pour la fabrication du pain, de biscuits et de céréales fortifiantes. On avait pensé que les farines de céréales, dont le Canada a des surplus annuels, pourraient être avantageusement mélangées à des déchets de poisson. On a obtenu, en particulier, un produit contenant 30 pour cent de protéines. Sa préparation est facile, il sèche rapidement, n'exige pas d'extraction au solvant et présente un goût et une odeur très acceptables. De plus, quand du gâteau de presse, sous-produit de l'industrie du jus de pomme en Nouvelle-Ecosse, est ajouté à des déchets de poisson avec de la farine de légumineuses, il a la propriété de masquer les goûts et odeurs caractéristiques de poisson. On pense que le gâteau de presse de l'ananas séché, pouvant exister en abondance dans les pays proches de ceux où le besoin d'un supplément en protéines est indéniable, serait susceptible de rendre le même service.

ADELANTOS TECNICOS EN CANADA

Las investigaciones sobre harina de pescado en Canadá se iniciaron en 1955 en la Estación de Tecnología de Halifax de la Junta de Investigaciones Pesqueras de Canadá. Las dos finalidades que se perseguían eran: un producto de proteína de alta calidad para el consumo humano y el aprovechamiento eficaz de los desechos y vísceras que quedan al filetear el pescado.

También otros países han encontrado procedimientos para la factura de harina de pescado, pero el principio fundamental es el mismo: extracción por solventes.

1. **El procedimiento del isopropanol** consta de:

(*a*) Tratamiento ácido de las vísceras con ácido polifosfórico a pH 5,5 para hidrolizar los colágenos.

(*b*) Extracción por solventes de la torta de prensa.

2. **Estudios de la extracción por solventes: procedimiento experimental y datos.** Se llevó a cabo una investigación sistemática de la eficacia de acetona e isopropanol como solventes, estudiando también el alcohol etílico y el tricloroetileno. Posteriormente se observó que el tratamiento ácido de las vísceras tenía el inconveniente de eliminar las proteínas solubles en agua y, con ello, de reducir el rendimiento del producto final. Guttmann (Halifax) se propuso demostrarlo presentando datos sobre la pérdida de nitrógeno proteico así como de los aminoácidos individuales. Además, esta investigación condujo a un *procedimiento simplificado* que daba un rendimiento más alto y un *método para conservar* la materia prima para la elaboración posterior.

3. **Nutrición.** Se ha demostrado que la harina de pescado (procedimiento isopropanol) es tan buena como la albúmina de huevo y, desde el punto de vista de la nutrición, más completa que la caseína.

4. **Utilización.** Aunque la harina de pescado para el consumo humano no se fabrica industrialmente en Canadá, algunos economistas hacen experimentos adicionándola a la harina de trigo para hacer pan, galletas y fortificar los cereales. Se creyó que las harinas de cereales de los que Canadá tiene excedentes todos los años, mezcladas con vísceras de pescado, podrían tener valor. Se obtuvo un producto en particular con 30 por ciento de proteína. Este producto se prepara y seca fácilmente, no exige extracción por solventes y su sabor y olor son aceptables. Además, la torta de prensa de manzanas, un subproducto de la industria de preparación de zumos de manzanas en Nueva Escocia, tiene la propiedad, cuando se añade a los desechos de pescado con harina de cereales, de enmascarar los sabores y olores a pescado. También se sugiere que la torta de prensa de piñas, que debería de abundar en los países próximos a aquéllos en que es mayor la necesidad de proteínas, podría tener un aprovechamiento igualmente útil.

FISH flour investigations in Canada were initiated at the Halifax Technological Station of the Fisheries Research Board of Canada in 1955. The objective was to produce a product of high-quality protein for human consumption, and in so doing utilize efficiently the fish offal resulting from filleting plant operations. Early investigations used an isopropanol process by Guttmann and Vandenheuval which is briefly described. Later modifications concerned studies by Dambergs on the efficiency of isopropanol and acetone as solvents. Present modifications involve a simplified process in which the raw material is directly extracted. These modifications are discussed along with results of nutritional assays on fish flour and product development studies.

Initial Investigations

Guttmann and Vandenheuval process.—In 1957, Guttmann and Vandenheuval (6) published a note describing a process which involved heating acidified fresh fillet waste from fish such as cod, haddock, and hake, followed by washing with water, pressing, and solvent extraction.

A brief description of the original process is as follows:

1. The heads are removed and discarded and the back bones and adhering flesh are ground in a meat chopper to ¼ inch size.

2. Equal weights of water and ground material are well mixed, acidified to pH 5·4–5·5, with polyphosphoric acid and the acidified slurry is heated and stirred for ½ hour at 150°F.

3. The slurry is centrifuged in a basket centrifuge and washed with hot water until the effluent is clear.

4. At this stage, the material, with roughly 55 per cent moisture, is mixed with twice its weight of isopropanol (86 per cent), heated to 180°F for 15 minutes and vacuum filtered.

5. After a second solvent extraction and filtration, the extracted material is dried in an oven dryer at 100°F for 24 hours.

The resultant dry material is screened through 16 and 20-mesh screens to separate bones and skins from protein and each fraction is ground in a Rietz grinder using $\frac{1}{32}$ inch screens.

The yields calculated on the basis of 100 lbs. of offal are, on the average: protein flour 10 lbs., bones and skins 5 lbs., and solids in acid extract, 4 lbs. The fish flour thus obtained is, for all practical purposes, white, tasteless, and odourless.

Production costs by this process have been estimated at 15 cents per pound based on continuous operation at 1,000 lbs./hour, exclusive of overhead. It is doubtful that a complete plant could be built for much less than 1 million dollars. Furthermore, based on an annual production of 2,500,000 pounds, the overhead charges would be approximately 12 cents per pound, thus making a total estimated cost of 27 cents per pound. The revenue derived from byproducts could reduce this figure slightly.

Efficiency of isopropanol and acetone.—In an effort to modify the process and lower production costs, Dambergs (1) investigated the efficiency of isopropanol and acetone as solvents. The investigation may be summed up as an exploration of the influence of water upon the efficiency of these two solvents as extractants.

It became evident, that, within the range of the objective set forth, the efficiency of the two solvents studied is greatest when their moisture contents are in the vicinity of 20–30 per cent. This is translated into extractions of optimum fatty materials and water solubles and minimum protein. Dambergs states: "Only a part of the fatty material can be extracted with dry acetone or dry isopropanol. Since both solvents are powerful dehydrants, the amount of fat extracted from a wet sample will depend upon the ratio of the solvent to the amount of water present in the sample. Maximum yields are obtained by adjusting the ratio between 20 and 30 per cent water in the liquid phase."

It was found that the water-soluble fractions consisting of amino acids, peptides, ammonia, and amines are responsible for the bitter taste often encountered in the finished product and, along with the fatty materials, contribute to the undesirable odours.

Acetone, although an excellent and cheap solvent, also imparted an objectionable taste and odour and was therefore rejected.

Present Modifications

The initial investigations led to a new process in which the raw material was extracted directly, thus bypassing two major steps in the process and consequently reducing production costs

Since Guttmann (5) demonstrated that the addition of 15 per cent by weight of pure isopropanol to groundfish offal will preserve them for a period of at least 2 months at room temperature, this mixture was prepared and held at room temperature for several days. After several experiments it was decided to carry out the first extraction by adjusting the alcohol content in the liquid phase to 60 per cent by adding pure alcohol to the already treated offal-alcohol mixture. At this concentration the phospholipids, with a negligible quantity of protein, are extracted, together with the greatest part of the water solubles.

A second extraction followed using 75 per cent isopropanol in the liquid phase. The fish flour thus obtained was in all respects equal to that obtained by the original process.

The savings resulting from this process have not yet been established. However, it is encouraging to note that the direct extraction of fish offal will produce 3 times more fish flour per unit time than will the original process.

The typical product contains 4·5 per cent moisture, less than 0·1 per cent fat, and about 8 per cent ash. The protein content is 90 per cent or better on a dry basis.

Nutritional Assays

The nutritive value of fish flour is better than egg albumin (Fig. 1). Larsen and Hawkins (8) state that the protein efficiency ratio, a measure of the promotion of growth by a given quantity of nitrogenous material, was the same for fish flour and egg albumin, and was 20 per cent higher than for casein. These values establish the protein of the fish flour tested as among the best in nutritional quality.

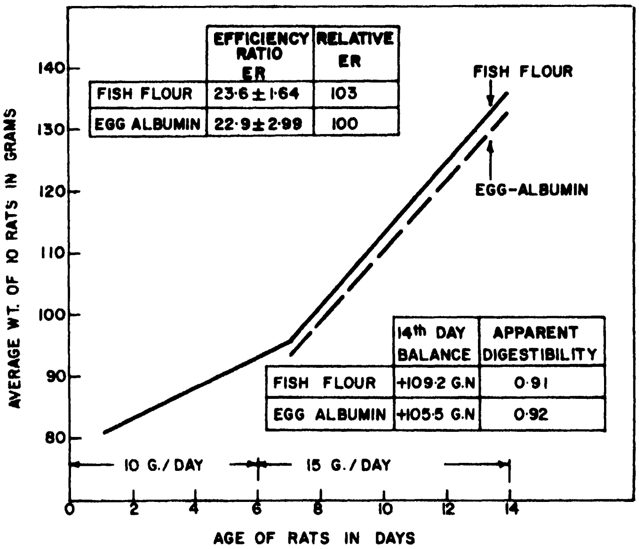

Fig. 1. The protein efficiency ratio of fish flour compared with that of egg albumin.

Product Development

Power and Fougère (17) attempted to develop a product similar to fish flour that would serve as an outlet for both surplus cereals and fish offal. Three parts of ground offal were mixed with one part of oatmeal and the resulting thick paste was extruded into pencil size sticks. After exposure to dry air for 5–10 minutes, these sticks became firm and could be transferred to a circulating hot air dryer where they usually dried quite readily. The ground dry product, containing roughly 30 per cent protein, when reconstituted into the original paste or porridge by boiling in water has a slight cooked fish taste and is slightly salty. In taste and odour it is far superior to fish meal, and its estimated cost is roughly 6 cents per pound.

Apple presscake, a byproduct of the apple juice industry, when added to fish offal with or without vegetable flour has the property of masking the fish taste and odour to some extent. Dry pineapple presscake, which may be abundant in countries close to those where the need for more protein is emphasized, could serve a similar purpose.

Several attempts to produce fish flour by solvent extracting fish meal with isopropanol were unsuccessful. It is very difficult to reduce fish meal to an odourless product. Another possibility is the solvent extraction of presscake from fish meal plants. Fish flour of good quality was successfully produced by solvent extracting presscake with one single extraction.

The Home Economics Section of the Canadian Department of Fisheries experimented with the use of fish flour in bread. Dough containing fish flour had a slight foreign odour which disappeared after the loaves were baked. In all cases, the loaves containing 10 per cent fish flour were heavy with fair volume and coarse, open grain. They were, however, regular in size and shape and quite palatable. Further results indicated that the 5 per cent level of fish flour was about optimal for brown bread. The colour was normal, as was also the odour and flavour. The texture and volume were judged ideal.

These baking experiments suggest the possibility of fortifying wheat flour with fish flour.

Conclusions

Fish flour can be produced by direct solvent extraction with isopropanol. Cost of production must be more accurately estimated. Dry fish protein products can be produced by mixing fresh offal with oatmeal and/or with fruit presscake. Fish flour can be added up to 10 per cent of the weight of wheat flour for baking bread.

TECHNOLOGICAL DEVELOPMENTS IN ICELAND

by

GUDLAUGUR HANNESSON

The fish meal produced in Iceland is chiefly exported and used as animal feed. Two attempts to produce fish flour have been made in Iceland.

A fish flour experiment carried out in 1938 consisted of vacuum drying skinned cod fillets which were then ground. No attempt was made to extract or deodorize this fish flour. The ground fish flour was successfully incorporated in recipes of various dishes such as soups and bread.

During 1952-54 efforts were made to produce fish flour. Experiments carried out by the staff of the Faxi Ltd., a large herring reduction plant, involved indirect steam cooking and air drying for dehydration followed by hexane extraction for defatting and deodorizing. The raw material used in these experiments was: beheaded, eviscerated cod, haddock and ocean perch; and fillet waste from the same. The fish-flour experiments may be divided into 3 groups: (i) fresh cod and haddock were processed by dry rendering in a small pilot plant. A portion of the batch was extracted with hexane. (ii) fresh fish and fillet waste were processed in a Farramatic fish-meal plant. The fish meal was subsequently extracted with hexane. (iii) same raw material as in (ii) was ground in a meat grinder and spread on trays for drying in a commercial salt fish dryer at 25°C, and was subsequently extracted with hexane.

Since 1954 no research has been carried out on either solvent extracted or non-extracted fish flour. In 1959, however, a fact-finding study was performed to decide on the feasibility of building a VioBin fish-meal plant for animal feed in Iceland. It was concluded in this study that the decisive factor against operating a VioBin fish-meal plant in Iceland was a foreseen increase in cost of production.

Production of fish flour in Iceland has failed primarily because of lack of interest on the part of potential buyers.

The Icelandic fish-meal manufacturers are of the opinion that greater emphasis should be placed on exploring the consumer acceptance of high-grade fish meal as a food in its own right.

DEVELOPPEMENTS TECHNOLOGIQUES EN ISLANDE

La farine brute de poisson produite en Islande est principalement exportée et utilisée pour l'alimentation animale. Il y a eu dans ce pays deux tentatives pour produire de la farine alimentaire de poisson.

Une expérience de production de farine alimentaire a été conduite en 1938 et consistait à sécher sous vide des filets de morue dépouillés puis à les broyer. Il n'y eut pas d'essai d'extraction ou de désodorisation de cette farine qui, par ailleurs, fut introduite avec succès dans des compositions culinaires variées telles que des soupes et du pain.

En 1952 54, il y eut de nouveaux efforts pour produire de la farine alimentaire de poisson. Les expériences conduites par le personnel de la Faxi Ltd., une grande industrie de traitement du hareng, utilisèrent la cuisson indirecte à la vapeur et le séchage à l'air pour la déshydratation, suivis d'une extraction à l'hexane pour le dégraissage de la morue, de l'églefin et du bar étêtés et éviscérés et les déchets de leurs filets.

Les essais sur la farine alimentaire de poisson peuvent être divisés en 3 groupes:

(i) La morue et l'églefin frais ont été traités par extraction à sec de la graisse dans une petite usine-pilote. Une partie de la charge était soumise à une extraction à l'hexane.

(ii) Le poisson frais et les déchets de filetage ont été traités dans une installation Farramatic à farine brute de poisson. La farine brute était soumise ensuite à une extraction à l'hexane.

(iii) La même matière première qu'au (ii) était broyée dans un moulin à viande, épandue sur des plateaux pour séchage dans un séchoir commercial à poisson salé, à 25°C, puis soumise à une extraction à l'hexane.

Depuis 1954, aucune recherche n'a été conduite sur la farine alimentaire de poisson soumise ou non à une extraction au solvant. En 1959, cependant, on a conduit une étude prospective pour décider de la possibilité d'implantation en Islande d'une installation VioBin à farine brute pour l'alimentation animale. Cette étude a conclu qu'un facteur décisif contre la mise en oeuvre d'une telle installation en Islande serait un accroissement prévisible des prix à la production.

La production de la farine alimentaire en Islande a échoué essentiellement du fait du manque d'intérêt des acheteurs possibles.

Les fabricants islandais de farine de poisson pensent qu'il faudrait s'efforcer de savoir si le consommateur pourrait accepter directement comme aliment de la farine brute de haute qualité.

ADELANTOS TECNICOS EN ISLANDIA

La harina de pescado fabricada en Islandia se exporta casi toda para emplearla como pienso. En dos ocasiones se ha tratado de producir harina para el consumo humano.

En 1938 se realizó un experimento que consistió en secar al vacío filetes de bacalao sin piel y molerlos después. No se trató de extractarla o desodorizarla. La harina se empleó satisfactoriamente en diversas recetas para sopas y pan.

De 1952 a 1954 se trató una vez más de producir harina de pescado para el consumo humano. Los experimentos realizados por el personal de la Faxi, Ltd., una gran fábrica reductora de arenque, consistieron en cocer al vapor indirecto y deshidratar al aire, seguido de extracción por hexano para desgrasar y desodorizar. La materia prima empleada en estos experimentos consistió en bacalao, eglefino y gallineta descabezados y eviscerados y desechos del fileteado de éstos. Los experimentos se hicieron en 3 partes:

(i) Bacalao y eglefino frescos se elaboraron mediante desecación en una pequeña instalación piloto. Una parte se extractó con hexano.

(ii) Pescado fresco y desechos de fileteado se elaboraron en una fábrica de harina Farramatic. La harina se extractó posteriormente con hexano.

(iii) La misma materia prima que en (ii) se molió en una picadora de carne y se esparció en bandejas para secar en un secador de pescado salado industrial a 25°C; posteriormente se extractó con hexano.

Desde 1954 no se han hecho experimentos con harina de pescado extractada con solventes o sin extractar, pero en 1959 se realizó un estudio para decidir la posibilidad de construir una fábrica de harina de pescado VioBin para producir piensos en Islandia. Se dedujo del estudio que el factor decisivo contra el proyecto era un aumento previsto en los costes de la producción.

La producción de harina de pescado para el consumo humano en Islandia ha fracasado principalmente por falta de interés de los posibles compradores.

Los fabricantes de harina de pescado de Islandia opinan que se debe dar más importancia al examen de la aceptación or parte de los consumidores de harina de pescado para el consumo humano de alta calidad como alimento por sí mismo.

THE fish meal produced in Iceland is chiefly exported and used for animal feeding. Two attempts, however, were made to produce an edible fish meal, one in 1938 and one in 1952–54. These are described along with the technological aspects of the later experiments. A fact-finding study in 1959 on the feasibility of building a VioBin fish-meal plant in Iceland, as well as present and future views on fish-flour manufacture, are also reported.

Fish-flour experiments in 1938

Raw material was skinned cod fillets for this experiment. The production was carried out under very sanitary conditions in a steam-jacketed vacuum dryer. The dried fillets were ground to about the fineness of medium fine commercial fish meal. No attempt was made to extract or deodorize the fish meal. The product was used experimentally in various recipes of fish soups, fish balls, and for bread making. Attempts to export this product failed. The information given here is limited as no written account of these experiments is available.

Fish-flour experiments in 1952–54

In 1948–50 a large herring reduction plant, Faxi Ltd., was built in Reykjavik. The production capacity of the plant was 675 tons per 24 hours. The plant was operated on the so-called Nygaard-method (13, 22). This patented method employs a principle of dehydration whereby a fat or oil heat transfer medium is used to effect the removal of water from the raw material. In the patent (13) it is specified that it is imperative for effective water removal that the combined oil content (both added and from the raw material being processed) be greater than the nonfat solids content of the mass. In the Faxi plant the Nygaard-type dehydration equipment consisted of an indirectly heated vacuum cooker. The raw material, herring, was cooked in its own oil (plus some added herring oil to maintain a certain, unspecified oil/solids ratio) and heated at a low temperature until dehydrated. The solids were then filtered from the oil and the filter cake extracted by hexane in a countercurrent, tower-type solvent extractor fabricated by Allis-Chalmer of Milwaukee, U.S. ((20) pp. 69–71).

The herring meal produced by this method was not intended for human consumption but rather as a high-protein feed supplement. However, the plant was never operated on a full time basis because of a series of poor herring seasons.

The fish-flour experiments were carried out by the engineers and chemists of the Faxi plant during 1952–54. The information given here is that obtained from the chief engineer of Faxi Ltd., at that time (2). Unfortunately, processing data, chemical and bacteriological analyses which were compiled in these experiments are not available.

A brief description of the experiments follows:

Experiment 1.—Fresh, good quality, beheaded, eviscerated cod and haddock were processed into fish meal by indirect steam cooking and drying. The resulting fish meal was then ground finely into flour. A small pilot plant-scale cooker and dryer were built for this purpose. The fish meal produced was of good quality and was believed to qualify as fish flour. Upon extended storage this fish meal became rancid. Bacteriological studies indicated that adequate sanitation had been used during processing. A portion of this batch of fish meal was extracted with hexane; the defatted fish flour had a faint fishy odour and taste, and had a fair keeping quality.

Experiment 2.—In these studies a Farramatic process plant manufactured by Farrar Boiler Works, Ltd. of England was used (3, 15). The plant had a 24 ton/24 hours capacity. This type of plant had been used on board a few Icelandic trawlers.

The Farramatic plant (3) employs a continuous live or indirect steam cooker, and a small screw-press. Two drying cylinders, heated with indirect steam, were used in these experiments. Raw material used was beheaded, eviscerated fish—cod, haddock and ocean perch—and the waste from these fish. The fish meal was extracted with hexane and ground finely. The fish flour produced from cod and cod fillet waste gave the best results in this experiment. Fish flour from ocean perch gave poor results.

Experiment 3.—These studies involved air drying with subsequent hexane extraction.

Raw material was the same as for the previous experiments. The fish and offal were comminuted in a fine meat grinder and spread on wooden-framed trays covered with fine mesh wire. The trays were placed in a commercial salt-fish dryer similar to that described by Linton and Wood (11). A fan blew the outdoor air through an air heater or directly into the dryer. A thermostat controlled the temperature at 24–25°C. Linear air velocity of 250–300 ft. per minute was maintained. Intermittent drying was used, the fish in the trays being stirred by a rake-like device, periodically. Drying was completed in a working day. A considerable amount of browning occurred during the course of air drying, likewise a fair amount of bad odours was produced. The air-dried fish mass was then extracted by hexane. The resulting fish flour was on the whole of poorer quality than that produced by indirect steam cooking.

These experiments were performed in 1952-54 and were then discontinued as no market could be established for the fish flour.

A fact-finding study in 1959 on the feasibility of building a VioBin fish-meal plant in Iceland

Prompted by the increased competition on the international fish-meal market a fact-finding study (23) was undertaken on behalf of the Icelandic fish-meal industry to evaluate the VioBin method (9, 10) for production of fish meal by azeotropic distillation. Of chief interest was the possibility of producing fish meal of higher protein content than by the conventional methods employed in Iceland. Considerations of secondary importance were:

(i) production of fish flour by alcohol extraction after the azeotropic distillation and (ii) that the method, *per se*, eliminates the odour problem usually associated with the manufacture of fish meal.

The conclusions reached refer to conditions in Iceland for production of commercial fish meal and are as follows:

The advantages of the method as compared to the conventional methods were considered to be: (i) the method yields more oil, thus, the meal contains more protein of higher biological value and should, even though the amount of meal obtained is less, be of a higher market value; and (ii) the method eliminates the odour problem to a very large extent.

The disadvantages of the method as compared to the conventional methods were considered to be: (i) the initial investment in building a VioBin plant is considerably higher than that in conventional fish-meal factories, and the corrosive nature of the solvent used should be taken into consideration in the construction of a VioBin plant; (ii) fuel consumption is 2–3 times greater than in conventional fish meal factories; and (iii) the fish oil obtained by the VioBin method is darker in colour than oil obtained by conventional reduction methods.

The study showed the cost of production to be higher with the VioBin method than with methods not using solvents. It was, therefore, concluded that building a VioBin plant in Iceland was not justified at the present. In addition, in regard to the solvent extracted fish flour, it is the author's opinion that the important question of harmful solvent residues has not been settled.

The present views of Icelandic fish-meal manufacturers on fish flour

The Icelandic fish-meal industry has shown little interest in production of extracted fish flour. Efforts made in this respect have failed primarily because of little interest shown by potential buyers. The added cost of extracting (defatting and deodorizing) commercial fish meal, even by a relatively simple method such as that proposed by Dabsch (16), is considered prohibitive. At present there is, however, some interest among Icelandic fish-meal manufacturers to explore the consumer acceptance of high-grade fish meal. It is thought probable that high-grade fish meal might find acceptance as a food in its own right which would not be expected with neutral-flavoured, solvent-extracted fish flour.

Future views on fish flour manufacture

The Icelandic fish-meal industry believes that future developments will place emphasis on production of edible fish protein concentrates in the under-developed areas themselves. Abundant supplies of fish are in the waters adjacent to many of these areas. Production of fish protein concentrate is no longer a technological problem but rather that of market development and education.

TECHNOLOGICAL DEVELOPMENTS IN SCANDINAVIA

by

KAARE BAKKEN

In the Scandinavian countries there has always been great interest in the production of fish meal which might be used for human consumption.

Many different processes have been developed, both for the production of fish meal and fish flour, but none of these has had a long life due to the inability to create a market for the products.

A few of the projects will be described here.

The Norwegian Fisheries Research Institute has built a pilot plant for the production of fish flour, and this will also be further described. The process adopted is based on simultaneous water removal and extraction with ethanol. The extraction is performed in three stages, and the miscella is separated from the solids after each stage by the use of screw presses (expellers).

Although the extraction takes place at ordinary room temperatures, the laboratory experiments showed that from pure fish meat might be produced an entirely neutral flour, which also had good storing qualities.

In Sweden a factory for the production of fish flour has been built by the firm "Astra". A short description of the process is given.

DEVELOPPEMENTS TECHNOLOGIQUES DANS LES PAYS SCANDINAVES

Les pays scandinaves ont toujours pris un vif intérêt à la production d'une farine de poisson qui pourrait être consommée par l'homme.

Des procédés nombreux et variés ont été mis au point pour la production de farines de poisson destinées soit à la consommation animale, soit à la consommation humaine. Tous ces procédés ont eu la vie courte du fait qu'il a été impossible de créer des débouchés pour les produits obtenus.

On décrira dans cette communication quelques-uns des projets mis en oeuvre.

L'Institut norvégien de recherches en matière de pêche a fait construire une usine-pilote pour la production de la farine de poisson. Cette usine sera décrite plus loin. Le procédé utilisé a pour base les opérations simultanées d'enlèvement de l'eau et d'extraction par l'éthanol. L'extraction a lieu en trois temps et, à chaque temps, le liquide est séparé des solides au moyen de presses à vis (pressoir continu).

Bien que l'extraction se fasse à la température de l'atmosphère ambiante, les expériences de laboratoire ont montré qu'il serait possible de produire, en partant de la chair de poisson pure, une farine absolument neutre qui présenterait de bonnes qualités de conservation.

En Suède, la maison "Astra" a fait construire une usine pour la production de la farine de poisson. Le procédé fera l'objet d'une courte description.

ADELANTOS TECNICOS EN LOS PAISES ESCANDINAVOS

En los países escandinavos siempre ha habido gran interés por la producción de harina de pescado que pudiese ser utilizada para el consumo por el hombre.

Se han ensayado muchos procedimientos distintos para producir de harina de pescado para el consumo por el hombre y el ganado, pero ninguno de ellos ha durado mucho tiempo debido a la incapacidad de crear un mercado para estos productos.

Se describirán aquí algunos de estos proyectos.

El Instituto de Investigaciones Pesqueras Noruego ha construído una planta piloto para la producción de harina de pescado y ésta también se describirá con más detalles. El método adoptado es el de la eliminación del agua y la extracción con etanol simultáneas. La extracción se realiza en tres etapas y se separan los líquidos de los sólidos después de cada una por medio de una prensa de tornillo (expulsores).

A pesar de que la extracción tiene lugar a la temperatura ambiente, los experimentos de laboratorio demostraron que sería posible producir, de carne de pescado pura, una harina totalmente neutra que a la vez tendría buenas características de conservación.

En Suecia la empresa "Astra" ha construído una fábrica para la producción de harina de pescado. Se dará una corta descripción del método.

THE first attempt to produce and market a fish meal for human consumption in Norway on a commercial scale was carried out by Professor Waage in the 1890's. This attempt is described along with early attempts of the Norwegian Fish Powder Corporation and the Norwegian Fisheries Research Institute. Later attempts by the Research Institute to produce an odourless and tasteless fish flour and a description of the pilot-plant process are reported. Analyses, both chemical and biological, are presented of the fish flour produced. Finally, the "Astra" process in Sweden is briefly described.

Initial experiments

Professor Waage in the 1890's was interested in producing an inexpensive article of food from fish in the form of a meal (flour) with good keeping qualities and with agreeable taste. He also contemplated a product that would be easy to use in cooking and that would not contain the usual odour and taste of dried fish.

The manufacturing process was as follows:

The coarsely chopped haddock fillets were dried in a high velocity hot-air stream at a temperature of 40°–60°C to a moisture content of 5–6 per cent, then finely ground and sifted. This product was especially suitable for use aboard ships and during expeditions, and proved very popular. In spite of the successful start, however, the corporation was unable to maintain the level of production at a profit and the factory had to close down after having been in production for about 4 years.

During the difficult marketing conditions for fish in the years 1930–1940, a good many attempts were made to find new products to use surplus fish. Here we shall consider only 3 projects, among the many suggestions made for the utilization of the fish surplus. Two developed beyond the experimental stage but regrettably no lasting market for the products was created. The third is still in the pilot plant experimental stage.

Experiments at the Norwegian Fish Powder Corporation

In the year 1936 this Corporation was founded for the production of fish meal for human consumption. The plant had a capacity of about 200 kg. of raw material per hour. The raw material, mainly fish meat from haddock and cod, was first cooked (coagulated) with live-steam injection at a temperature of about 60°C. After cooking, the mass was pressed in order to remove the glue materials. That remaining, the presscake, was dried in a steam heated drier under reduced pressure at a temperature of about 40°C. Drying time was about 1 hour.

During cooking and drying, the fish meat was defibred, and the desired fluffy form was obtained without further treatment. The bones, which were separated by sifting, were ground in a special disintegrator and mixed into the fluffy powder.

The product was entirely satisfactory from the quality point of view, but in spite of a positive reaction from the market investigations, the factory never moved beyond the trial production period and was abolished after a short time.

Experiments at the Norwegian Fisheries Research Institute

At the Research Institute a good deal of work was done to find new products and new production processes to create better marketing conditions for the fish surplus. Also, new raw material entered the picture in the form of fillet waste from the ever-increasing fillet production. New processes were investigated whereby the fillet waste could be utilized as articles of food instead of animal feeds.

One of the products given the most attention was the production of a fish flour suitable for mixing with bread flour. Instead of traditionally cooking, pressing, and drying the presscake, which requires expensive machinery and gives a low yield, the fish pulp was dried in stages and in ordinary hot-gas driers without recourse to cooking and to pressing processes.

When raw fish meat is dehydrated in the usual fish meal driers, the pulp will tend to clog together and stick to the walls of the drier. This was avoided in the new process by finely dividing the raw material and thoroughly mixing it with partly-dried fish in such proportions that the mixture formed a semi-dried mass which could be dehydrated without difficulties in common directly-fired, hot-gas driers.

This method was very simple and gave a light coloured flour with only a slight fishy odour and taste when assorted and washed fillet waste or eviscerated, beheaded, and washed white fish were used as raw material. Trial production of this flour for human consumption was started at the beginning of the war and acceptability tests showed that a mixture of 5–6 per cent of the product in bread flour was undetected by the majority of consumers.

Commercial plans for mixing the fish flour with bread flour were not realized during the war, but the manufacturing method itself was so successful that most of the fish-meal factories in Norway today use this principle and could therefore be called potential producers of fish meal for human consumption when market conditions permit such production.

The production of odourless and tasteless fish flour

The meal produced by the previously mentioned method had a slight fishy odour and taste. After solvent extraction with alcohol or acetone, however, an entirely odour- and taste-less meal could be produced which would also keep well during storage. When a neutral product is indicated, however, it seems desirable that the dehydration and extraction should be conducted in the same step.

For a number of years, the Research Institute has experimented with dehydration of ground fish with ethanol at room temperature. When ground fish (paste) and ethanol are intimately mixed, most of the protein is coagulated and the resulting mass may easily be pressed and the alcohol and water removed. By repeated treatment of the press cake with ethanol, the water content can be reduced to the desired minimum. Economic considerations, of course, determine how far the reduction of the water content should be carried out advantageously with alcohol as compared to removal of the remaining water in common driers.

Theoretical considerations and practical experiments in the laboratory pointed towards a three-stage plant as being the most feasible. A pilot plant constructed on these principles was designed and erected to study the practical process, and also to produce samples for marketing investigations (Fig. 1 and Fig. 2).

Description of the pilot plant process

The raw material is ground to a paste in a meat grinder and transported to a hopper at the top of the plant. This is done by hoist, since the paste becomes increasingly viscose if agitated too much by pumping. The paste is fed at intervals into an adjustable continuous feeder which maintains a uniform feed of raw material to a first extractor where it is mixed with miscella from one of the later stages.

From the extractor the mass overflows to a screw press or expeller where the miscella is drained off and pumped over a vibrating screen to the miscella storage tank. The same procedure is repeated 3 times. This is not a true counter-current process as each individual stage has parallel flow, but the flow through the three different stages may be counter-current or varied so that fresh solvent is introduced at two points.

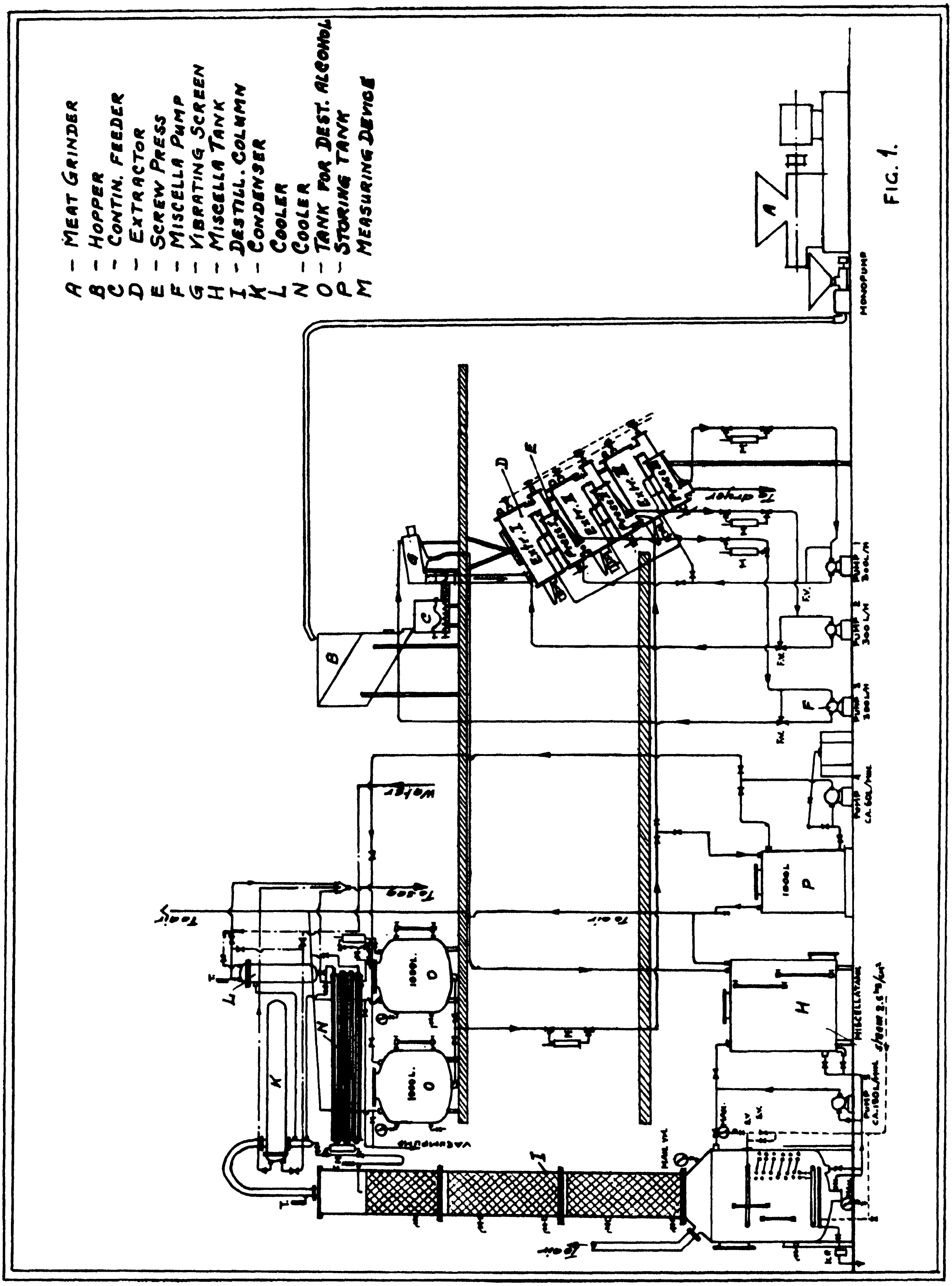
A - Meat Grinder
B - Hopper
C - Contin. Feeder
D - Extractor
E - Screw Press
F - Miscella Pump
G - Vibrating Screen
H - Miscella Tank
I - Destill. Column
K - Condenser
L - Cooler
N - Cooler
O - Tank for Dest. Alcohol
P - Storing Tank
M - Measuring Device
Monopump
Pump 1 300 L/M
Pump 2 300 L/M
Pump 3 300 L/M
Pump 4 ca. 60 L/min
To dryer
Water
To air
Miscellatank
1000 L
Vacuumpump

FIG. 1.

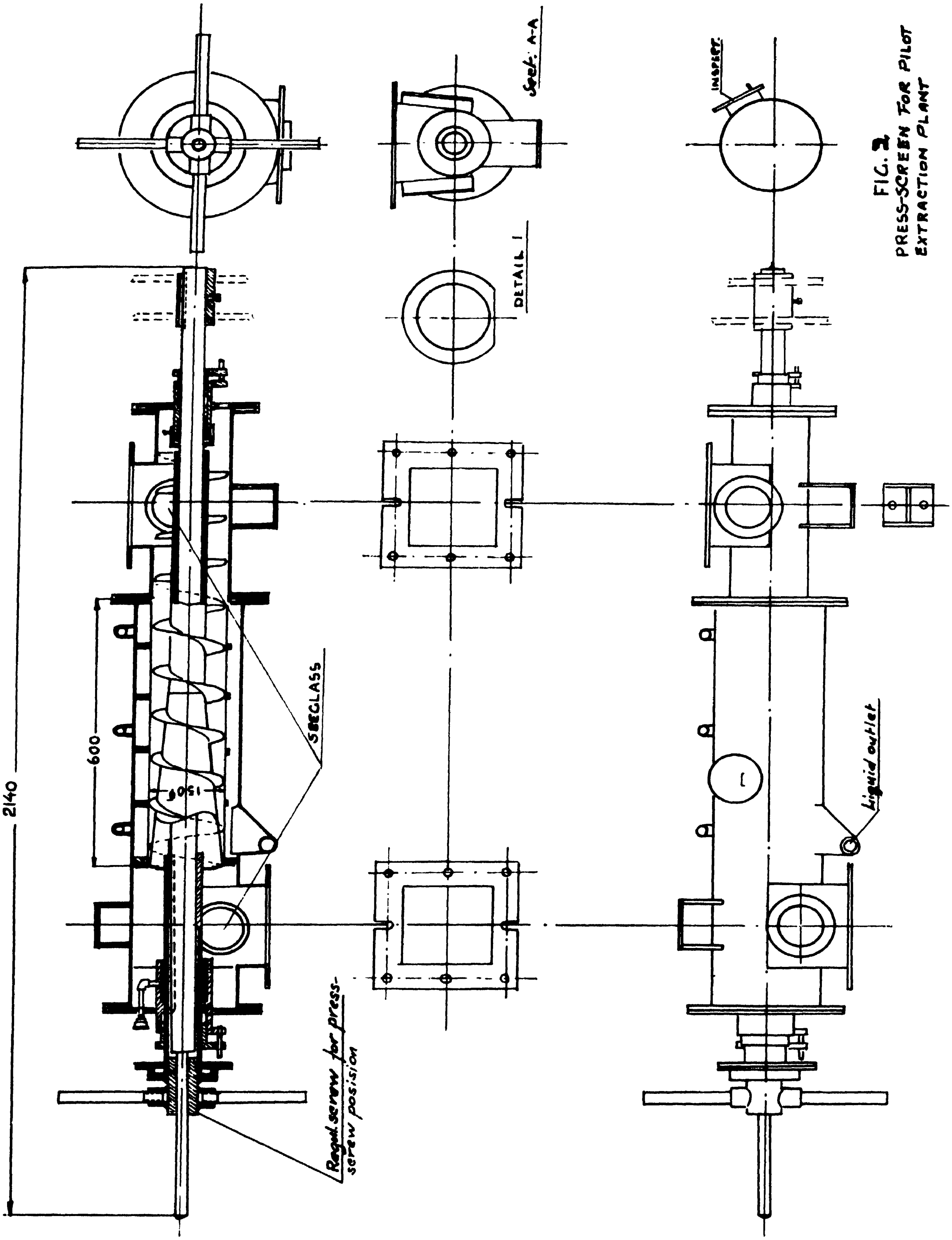

FIG. 2
PRESS-SCREEN FOR PILOT EXTRACTION PLANT

The pressure exerted on the presscake in the expeller may be varied by moving the cone-shaped expeller screw along the revolving shaft by turning the spoked wheel on the end. The extractor is supplied with a steam jacket so that the mixture can be heated during extraction if desired.

An assembly of three extractors and three screw presses is placed on an angle of about 30° from the horizontal in order that the material will overflow from the extractor at a proper level. After being thoroughly mixed with the liquid, the mass falls into the feed end of the expeller. The liquid is drained off through a sieve plate surrounding the expeller screw and pumped to a previous stage and, in the case of the top stage, to the miscella storage. The set of three extractors as well as the set of three expellers each has a common drive through an infinitely variable speed variator.

The alcohol in the miscella is recovered in a distillation column. Due to accumulation of sediment in the miscella the batch type of distillation has been used and the sediment may be emptied from time to time at the bottom of the kettle. The distillation column has a capacity of about 100 litres of up to 90 per cent (weight) of alcohol per hour.

The drying of the meal is presently done in an adjoining fish-meal factory with vacuum steam jacketed driers. In this factory it is also possible to convey the material through a basket centrifuge before drying.

The extraction plant is found to work best at a capacity of about 120 kg. per hour of raw material charge, although it was designed for a somewhat higher capacity.

A plant of this type must have uniform flow through all parts in order to obtain proper balance. Owing to the tendency of fish paste to stick and clog passages, sieves, pipes, etc., the balance may easily be upset and a proper presscake will not be obtained.

Although only a comparatively small amount of fresh alcohol feed should theoretically be required, it has been necessary to increase the amount of feed to improve the pressability of the material. The amount of alcohol actually used has been in the order of 50–90 kg. alcohol per 100 kg. raw material. The miscella from the last extractor will then have a concentration of 50–60 g. of alcohol per 100 g. of miscella. The miscella leaving the system from the first extractor will, according to conditions, contain 20–30 per cent alcohol and 3·5–4 g. of dry material per 100 g. of miscella. This will give a loss of the raw material equal to 15–20 per cent if the extracted dry material is not utilized.

Experimentally, 40–50 per cent dry material in the presscake has been obtained from the last stage. Further removal of liquid from the final presscake is possible by centrifuging which may give a content of 50–60 per cent dry material.

During experiments at the laboratory with finely ground fish fillet, an extraction time of 20 minutes in each stage was found to be more than sufficient to obtain equilibrium between the solvent and the material to be extracted.

The conditions of equilibrium between the concentration of alcohol in the liquid phase of both the miscella and the presscake that were obtained in laboratory experiments have not been observed in the experiments made with the pilot plant up to the present. Using fillet waste *with bones* we have always observed that the concentration of alcohol has been higher in the miscella than in the corresponding presscake liquid phase. All indications seem to point towards the bones as being the cause of this anomaly. This may explain why we have so far been unable to produce a flour from the pilot plant with a quality and storage life equal to that of the flour obtained from the laboratory experiments.

During our experiments with the pilot plant we also observed that some raw material requires a good deal more fresh alcohol feed than expected in order to give the mass a pressable consistency. We are therefore considering substituting a centrifuge for the last press in an attempt at using less pressure on the mass during the various stages. Additional work is needed to determine the critical conditions for processing various raw materials of interest.

At the present time it is therefore not yet possible to say with certainty whether a cold extraction with ethanol or other water-removing solvents has any advantages over the solvent extraction of commercial fish meals.

Analysis of the meal (flour)

According to the amount of bone in the raw material used (fillet waste), the meals have a content of 70–85 per cent protein, 6–20 per cent ash, and about 0·5–1 per cent fat. The net protein utilization (N.P.U.) of a few typical samples has been compared with freeze-dried fillet and spray-dried egg white.

Six groups of rats were used, each group containing 3 males and 3 females, with initial weights of about 75 g. Each of the meal samples was given to a rat from the same brood and same sex. The food contained 8 per cent protein and each rat was fed 10 g. per day.

The result is given in this table:

	Nitrogen balance per cent	*Apparent digestibility*	*N.P.U. (Egg — 100)*	*True digestibility (Egg -- 100)*
Fish Flour I	61·1	85·3	93·1	100
Fish Flour II	60·0	84·0	93·0	100
Freeze-dried fillets	56·2	84·3	88·2	100
Egg white	68·0	83·1	100	100

The fish meals were clearly inferior to egg-white with reference to the N-balance but it may be pointed out that the values generally are relatively high. With regard to digestibility, the fish meals were at least as good as the spray-dried egg-white.

SWEDEN

In 1960 "Astra" in Sweden built a pilot plant for the production of fish flour. The plant has produced a few hundred tons of the product, all of which has up to the present time been marketed in Sweden.

The process starts directly from fresh fish which is processed within 24 hours after unloading from the fishing vessels.

The fish is first cooked with constant heating and stirring.

The fat in the fish is then extracted with various solvents; however chlorinated solvents such as dichloroethylene have been avoided.

The solvent is introduced into a mixing tank where the extraction is carried out. After the solvent has been removed from the solid, the extraction operation is repeated until the de-fatting is sufficiently complete. A similar operation is used in the deodorizing process.

The solvents used for the deodorization are removed in a drier. Simultaneously the content of water is reduced to the required amount. The product is finally ground into fine particle size.

The fat is separated from the solvent by the use of simple distillation and forms a by-product from the process.

The odour and taste constituents which are carried away by the solvents are again removed from the solvent in a distillation column.

Bacteriological control as well as determination of protein content, fat, water, and minerals are carried out every day. Concurrently, taste and odour tests are also carried out.

TECHNOLOGICAL DEVELOPMENTS IN SOUTH AFRICA

by

G. M. DREOSTI

In 1937, South African investigations were begun to find a tasteless, odourless fish flour for enriching cereal products for human consumption. The Fishing Industry Research Institute (FIRI) developed a suitable process. Hake, maasbanker and pilchard are successful raw materials. Even year-old fish meal was found useful for fully acceptable fish flour. The highest yield is obtained by extracting dry, normal fish meal with ethyl alcohol having as low a moisture content as is conveniently possible. Using batch extraction, it was found the finer fish meal is ground, the more rapid is the extraction when it is shaken with alcohol. In percolation, unground meal was found preferable. Methods of recovering the used solvent and using the residue have been developed. The paper gives specifications for fish flour production and analytical data.

The protein fraction of FIRI fish flour is usually high quality. If the level of supplementation is sufficiently high, fish flour can increase the assimilable protein content of bread to an appreciable extent. Rats are able to utilize fish flour's mineral component. However, the potassium content was often found too low to afford normal growth when fish flour provided the sole mineral source in the diet. Formulae based on skimmed milk powder or casein have been found uniformly satisfactory for cure of kwashiorkor and maintenance of cure in convalescent infants. Experiments to date on diets containing 10 or 40 per cent FIRI fish flour indicate the fish flour samples had characteristics which made them unsuitable for this purpose. The use of fish flour to prevent kwashiorkor has not yet been investigated.

DEVELOPPEMENTS TECHNOLOGIQUES EN AFRIQUE DU SUD

En 1937, des recherches furent entreprises en Afrique du Sud pour obtenir une farine alimentaire de poisson inodore et sans saveur pouvant enrichir les produits des céréales pour la consommation humaine. Le Fishing Industry Research Institute (FIRI) a mis au point un procédé convenable. Le merlu, le saurel et le pilchard ont donné pleine satisfaction comme matières premières. On a pu utiliser même de la farine brute de poisson vieille d'un an pour obtenir une farine alimentaire entièrement acceptable. La plus grande production est obtenue par une extraction de la farine brute et sèche normale avec de l'alcool éthylique présentant une teneur en eau la plus basse possible. Avec une extraction discontinue, plus la farine brute est moulue fine, plus l'extraction est rapide quand on brasse la farine avec l'alcool. Avec une extraction par percolation, la farine brute non moulue s'est montrée préférable. On a mis au point des méthodes de récupération du solvant usé et d'utilisation du résidu. L'article donne des spécifications pour la production de farine alimentaire de poisson et des données analytiques.

La fraction protéique de la farine alimentaire de poisson du FIRI est habituellement de haute qualité. Si le niveau de supplémentation est suffisamment élevé, la farine alimentaire de poisson peut élever la teneur en protéines assimilables du pain dans une large mesure. Les rats sont capables d'utiliser les constituants minéraux de la farine alimentaire de poisson. Cependant, la teneur en potassium s'est souvent montrée trop basse pour permettre une croissance normale quand la farine alimentaire de poisson se trouve être dans le régime la seule source en minéraux.

Des formules basées sur la poudre de lait écrémée ou la caséine se sont montrées uniformément satisfaisantes pour le traitement du kwashiorkor et la poursuite de ce traitement chez les enfants convalescents.

Jusqu'à ce jour, des expériences sur des régimes contenant 10 à 40 pour cent de farine alimentaire de poisson FIRI indiquent que les échantillons de farine alimentaire ont des caractères qui ne leur permettent pas de convenir à cet objet. L'emploi de la farine alimentaire de poisson pour prévenir le kwashiorkor n'a pas encore été étudié.

ADELANTOS TECNICOS EN SUDAFRICA

En 1937 en Sudáfrica se iniciaron investigaciones encaminadas a encontrar una harina de pescado inodora e insípida para enriquecer los productos de cereales destinados a la alimentación humana. El Fishing Industry Research Institute (FIRI) encontró un procedimiento conveniente. Merluza, jurel y sardina sudafricana son materias primas que han dado buen resultado. Incluso la harina de pescado de un año de edad puede emplearse para obtener una harina alimentaria enteramente aceptable. El mayor rendimiento se obtiene por extracción de la harina normal seca con alcohol etílico, con un tenor deagua lo más bajo que sea factible. Empleando la extracción discontinua, se ha observado que cuanto más fina es la harina más rapida es la extracción cuando se agita con alcohol. Con la extracción por filtración, la harina bruta no molida demostró ser preferible. Se han encontrado procedimientos para recuperar el solvente empleado y utilizar los residuos. El artículo da especificaciones para la producción de harina de pescado comestible y datos analíticos.

La fracción proteica de la harina de pescado de la FIRI es usualmente de alta calidad. Si se adiciona en cantidades suficientes, la harina de pescado puede incrementar en forma sensible el contenido de proteína asimilable del pan. Las ratas son capaces de utilizar los constituyentes minerales de la harina de pescado, pero el de potasio ha resultado ser demasiado bajo con frecuencia para permitir un crecimiento normal cuando la harina de pescado es la única fuente de minerales en la alimentación. Fórmulas basadas en leche descremada en polvo o caseína han dado resultados uniformemente satisfactorios para el tratamiento del "kwashiorkor" y mantener la cura en niños convalecientes. Los experimentos realizados hasta ahora con dietas que contienen de 10 a 40 por ciento de harina de pescado FIRI indican que las muestras de harina de pescado tienen características que no las hacen convenientes para esta finalidad. El empleo de harina de pescado para prevenir el "kwashiorkor" todavía no se ha investigado.

THE history of fish flour in South Africa starts in 1937 when Dreosti in collaboration with F. S. Mendel began investigations aimed at producing a tasteless and odourless fish flour for enriching cereal products intended for human consumption. The result of this early trial is reported along with a general historical account of more recent studies. Technological aspects of the later investigations are noted separately and include discussions on such variables of processing as types of fish and solvents used, yields of fish flour, extraction rates and methods, stripping of solvent and recovery of used solvent, and residues left after recovery of the solvent. Production in South Africa had to comply with some tentative specifications which are noted. Finally, a section on results obtained to determine the nutritive value of fish flour is reported and includes such considerations as chemical composition, bacteriology and toxicity, the protein value as such and supplemental value of fish flour in bread, mineral content, and fish flour as a source of protein for remedying and preventing kwashiorkor.

Historical

A product was developed from the initial investigations on fish flour processing which was virtually bland but which tended to revert to a slightly fishy or bitter taste upon prolonged storage. The project was discontinued temporarily due to lack of public interest.

In 1951, the Minister of Health announced plans for the enrichment of staple foods with protein-rich materials, and both the Fishing Industry Research Institute (FIRI) and the Marine Oil Refiners (MOR) considered that they were able to produce neutral fish flour which could be incorporated in brown bread. Briefly, the primary aim in South Africa was to produce not the best fish flour in the world, but material that would be undetectable by odour or taste when used for protein enrichment. MOR employed a pressure extraction process operating at temperatures of 120°C and higher; while FIRI concentrated on extraction by means of ethyl alcohol at atmospheric pressure. FIRI found that its process retained the biological value of the protein, while the pressure process resulted in substantial damage to the biological value.

After producing more than 1,000 tons of this fish flour and using it with complete acceptability for enriching brown bread, the industrial venture was temporarily suspended because the enriched bread did not reach those most in need of improvement of their diet, viz. non-European infants and young children. Nevertheless research is continuing with a view to using fish flour (and fish meal) in other ways for helping those sections of the population that are in urgent need of more good protein.

The best and most economic process was found to be extraction by percolation of the solvent, at boiling point, through unground fish meal in a continuous counter-current flow system. Ethyl alcohol was the only solvent that removed the odour and flavour of fish, presscake, and fish meal consistently well. The spent solvent was readily recovered by simple distillation, and deodorized by active charcoal in the vapour (or liquid) phase to remove fishy odours. The alcohol residues were dark, viscous, foul smelling acid materials, and were discarded.

Fish meal was used in preference to fish because (i) of the erratic nature of the fishing operations—explained by the original name, Cape of Storms, (ii) the extractor could be used regularly and continuously throughout the year, and (iii) a much smaller plant was needed than would have been the case if fish had been used.

Both whole fish meal and ordinary fish meal were used, and the protein quality and the mineral and vitamin contents of the final products varied widely. The fish meal used by the operators of the pilot plant was not always made from perfectly fresh fish. Some batches were prepared from formalin-treated fish which had undergone partial enzymic autolysis. For these reasons it was impossible for the operators to produce fish flour of consistently uniform high quality.

Nevertheless, the fish flour when added in small quantities to wheat flour enhanced the protein quality of the latter to an appreciable extent. This was proved consistently in Pretoria, Cape Town, the United Kingdom, and Holland.

The possibility of using fish flour in diets for protein deficient children is being studied at present. Both the National Nutrition Research Institute, Pretoria, and the Clinical Research Unit of the University of Cape Town used fish flour made in the old pilot plant for treating convalescent cases of kwashiorkor. The South African fish flour used in the Pretoria experiments, though it appeared to be free from toxic substances or harmful bacteria, was unsuitable as will be reported later when the nutritive value of fish flour is considered.

In contrast, the South African FIRI fish flour used at the University of Cape Town as a supplement of maize and pea flour gave good results. Briefly it was found that a mixture of maize 60, pea flour 30, and fish flour 10, having a protein content of 20 per cent, gave a nitrogen retention that was not different from that of a pure milk diet at protein intake levels both above and below 2·5 g. per kg. per day. A mixture containing maize 60, pea flour 30, and skim milk powder 18, having a protein content of 18 per cent, resulted in nitrogen retentions that were not different from that of a whole milk diet at all levels of protein intake. These studies demonstrated that relatively small amounts of fish flour (10 per cent) or milk powder (16·5 per cent) added to a 2 : 1 maize–pea mixture gave protein with a nutritive value not different from that of a whole milk diet at all levels of protein intake.

But the problems of marketing and use of fish flour in the diets of those in need of extra protein in the distant rural areas remain the major issues to be solved before the product can be used effectively in combating malnutrition.

Technological aspects.—(Experiments at the Fishing Industry Research Institute, Cape Town.)

Type of fish.—Hake, maasbanker, and pilchards have been used successfully.

Solvents.—A large number of solvents were tried in the early experiments.

1. Hexane, heptane, cyclohexane, etc.: None of the solvents extracted as much material from the fish meal as ethyl alcohol but, although the extracted products were neutral in odour and flavour immediately after preparation, they acquired a slightly fish flavour or odour on storage at room temperature. In some instances this reversion occurred within a few days.

2. Iso-butyl and iso-propyl alcohol: These solvents also extracted less material than ethyl alcohol; the fish flour retained a solvent taint even after prolonged steam stripping under vacuum.

3. Acetone: This imparted a taint to the flour which

could not be conveniently removed by steam stripping.

4. Ethyl alcohol plus 10 per cent ethyl acetate: This mixture gave a good final product; however, the inclusion of the ethyl acetate was unnecessary under conditions of thorough extraction, and the additional cost was therefore not justified. Moreover, corrosion of the plant was increased.

5. Ethyl alcohol plus 10 per cent hexane: Alcohol containing up to 10 per cent hexane was used successfully but the mixture gave additional recovery problems due to differences in boiling point.

6. Water: Extraction by means of ordinary water at 100°C gave neutral products, but reversion occurred in some instances. There was also danger of lowering the biological value of the protein. Lower temperatures were not entirely satisfactory.

7. Pressure extraction with hexane: Extraction of fish meals with hexane at 95°C imparted a musty flavour to the flour, and reversion occurred after storage for a week or so at 37°C.

As a result of these tests, and many others, it was decided that ethyl alcohol was the best solvent for extraction.

Yield of fish flour.—The yield of fish flour from fish meal depends on a number of factors, e.g. fat and moisture content of fish meal, its degree of fullness, soluble protein content, and moisture content of the alcohol.

The highest yield is obtained by extracting dry, normal meal with alcohol having as low a moisture content as conveniently possible. A further advantage of drying the fish meal before extraction is that rectification of the used solvent is simplified and the cost reduced.

Factors affecting rate of extraction.—The finer the fish meal is ground, the more rapid the extraction when it is shaken with alcohol. However the difference in rate of extraction between normally milled meal, i.e. to pass 10-mesh, and unground meal (as it comes from the drier) is far less than the difference between the rates for normally ground meal and very finely ground meal.

This fact is important, as the rate of percolation of solvent through a layer of unground meal is much faster than through normally ground meal; and it is preferable to use unground meal for extraction by percolation.

The temperature of the solvent during extraction has a considerable effect on the rate of extraction. The weights of extract (g.) per unit volume (c.c.) of solvent after various periods, for example 20 minutes extraction, could be crudely represented by the formula $y = 0{\cdot}0046X + 0{\cdot}237$ where y = g. extract and X = temperature of extraction.

Method of extraction.—Basically two types of extraction were studied.

1. Batch extraction: In this system, the fish meal is extracted in a horizontal rotary extractor or in any other extractor in which the fish meal is agitated.

Different ratios of meal to solvent, viz. 1 : 3, 1 : 2, 1 : 1½, and 1 : 1 were tried using batch extraction. After 20 minutes, amounts of material extracted were 13·2 per cent, 13·4 per cent, 13·1 per cent, and 11·7 per cent of the weight of the fish meal respectively.

The efficiency of batch extraction depends largely on the amount of hold-up between each extraction, and thus varies according to the method of filtration used. With vacuum draining the hold-up could be reduced to as little as 12 per cent of the weight of the meal; with gravity draining it averaged about 60 per cent. On using 3 : 1 ratio of alcohol to meal and applying vacuum filtering, the average percentages of the total extractable material removed in each successive 20 minutes extraction was 70·3 per cent, 17·7 per cent, 6·1 per cent, 3·5 per cent, and 2·4 per cent. When solvents were re-used, as in counterflow, larger amounts of material were extracted than with the new solvent for each successive extraction.

The agitation of the fish meal in the batch system considerably increases the amount of fines passing 150-mesh, e.g. from 1·1 per cent to 12 per cent for an ordinary fish meal and from 7·8 per cent to 29·4 per cent for a finely ground meal.

2. Percolation: In this system the alcohol is made to pass through a layer of fish meal. In a counter-current system 6 cylinders of fish meal were used in series, the first in order of alcohol flow being removed each 20 minutes and a new cylinder added at the end of the line.

Samples of the meal were withdrawn for examination after steady counterflow had been established, as evidenced by a constant composition of the used solvent leaving the extractor. Each of the 6 cylinders contained 100 g. of unground fish meal plus 160 ml. alcohol of which 85 ml. was in the meal and 75 ml. in the space above it. When the average flow of alcohol was 112 ml. per 20 minutes, the meal was almost neutral. The residue in the spent solvent averaged 10·5 per cent based on the weight of the meal as against 12·5 per cent to 13 per cent when meal of the same lot was batch-extracted five times in succession using a solvent to fish meal ratio of 3 : 1. In the latter case 15 ml. of alcohol were used per g. of fish meal as compared with 1·12 ml. per g. in the counterflow system.

From further tests it became clear that neutral meal could be produced using this low solvent-to-meal ratio in counterflow, provided that the rate of flow was reduced and the extraction period thus increased.

The rate of percolation of hot alcohol through fish meal was studied using columns of normal or unground fish meal approximately 1 square foot in cross section, the hot alcohol flowing downwards through the fish meal. The depth of fish meal varied between 9 in. and 26 in. and the "head" of alcohol above the meal varied between 0 in. and 13½ in.

The rate of percolation confirmed the theoretical consideration that, up to a height where compression of the lower layers occurs, the rate of percolation is independent of the height of the meal column, and is approximately proportional to the square root of the "head" of the supernatant liquid. Reversing the flow of solvent led to immediate channelling.

Percolation through unground fish meal was rapid. For instance, the rates of percolation of hot alcohol through a column of fish meal of 12 in. depth were 0·9, 5·6, and 8·12 lb. per square foot per minute for fish meals that were finely ground (61 per cent retained by 65 mesh), relatively coarsely ground (71·5 per cent retained on 65 mesh) and unground (83·2 per cent retained on 65 mesh) respectively. Moreover, the rate of extraction from unground fish meal is only slightly slower than for normally ground meal. Therefore unground meal was used for extraction by percolation and finely ground meal for batch extraction.

Stripping of solvent from fish flour.—Various methods of removing the last traces of solvent were tried. The flour was rendered solvent-free in about 10 minutes at 80°C either by air stripping at atmospheric pressure or under a vacuum of 10 in. or 20 in., using an air-flow of 1,700 c.c. per minute, or by steam stripping under 26 in. vacuum using a steam flow of 2,500 c.c. per minute.

Recovery of used solvent.—Used solvent is readily recovered and partially dehydrated by straight distillation with suitable temperature control. The condensed vapours, however, have a strong fishy odour. The alcohol is deodorized in the vapour phase or in the liquid phase by means of activated charcoal. About 6 per cent by weight of activated charcoal is needed. The charcoal is regenerated with steam at atmospheric pressure without removing it from the column in the plant.

Residue.—The residue left after recovery of the alcohol is a dark, viscous material, acidic in nature, with a strong odour. The residue is corrosive, but this can be overcome by neutralization. The high phosphorus content of the residue suggests that it might contain at least 25 per cent phospholipids of the lecithin type. This material probably causes the emulsifying tendency of the residue, because of which the Leather Industries Research Institute found the material to be suitable, under certain conditions, for leather treatment.

Fully dried residue has been found by the Fuel Research Institute, Pretoria, to have a calorific value of 12,620 B.T.U. per lb. and thus to be equivalent to coal of good quality.

The Department of Botany of the University of Cape Town found that plant growth is promoted without damage to plants or soil at a dosage of 100 lb. residue per acre.

Fish flour specifications.—The factory and plant had to comply with the general standards existing for the

TABLE I

Chemical composition of fish flour and certain protein-containing materials

	Moisture (%)	*Protein* (%)	*Fat* (%)	*Ash* (%)	*Fibre* (%)	*Carbohydrate* (%)	*Calcium* (*mg./100g.*)	*Magnesium* (*mg./100g.*)	*Iron* (*mg./100g.*)	*Phosphorus* (*mg./100g.*)	*Vitamin* B_1 (*mg./100g.*)	*Riboflavin* (*mg./100g.*)	*Niacin* (*mg./100g.*)
Fish Flour, FIRI													
1. Composite sample received January, 1957	5·0	74·0	0·6	19·45	—	—	5660	292	39·7	3240	0·05	0·24	0·31
2. Composite sample received September, 1958	7·0	73·8	1·0	14·80	—	—	4600	261	50·4	2640	0·04	0·22	0·43
3. Sample received January, 1958	3·9	76·6	0·2	19·70	—	—	5540	—	70·2	3850	0·07	0·47	0·39
Average	5·3	74·8	0·6	17·98	—	—	5267	276·5	53·4	3303	0·05	0·31	0·38
Fish Flour, VioBin													
1. Sample received August, 1957	4·0	82·4	0·1	13·09	—	—	2450	—	33·1	2110	0·01	0·28	2·00
2. Sample received June, 1958	4·6	84·4	0·4	10·10	—	—	1640	263	31·0	1700	0·01	0·27	0·48
3. Sample received August, 1958	5·1	83·7	0·1	9·70	—	—	1600	212	29·4	1930	0·05	0·33	0·91
Average	4·6	83·5	0·2	10·96	—	—	1897	237·5	31·2	1913	0·02	0·29	1·13
Skimmed Milk Powder													
1. Sample received December, 1958	4·4	35·8	1·0	8·25	—	50·6	1330	—	1·6	—	0·54	1·28	0·84
2. Sample received January, 1959	2·7	35·3	0·6	8·70	-	52·7	1330	—	0·9	—	0·50	1·26	0·87
Average	3·6	35·6	0·8	8·48	—	51·7	1330	—	1·3	—	0·52	1·27	0·86
Groundnut Flour, Defatted													
1. Sample received May, 1958	6·1	36·2	1·1	4·82	5·6	46·2	114·1	—	27·7	—	0·82	0·44	23·1
2. Sample received December, 1958	5·7	44·7	2·5	5·10	5·4	36·6	111·0	—	29·0	—	0·74	0·10	14·0
3. Sample received December, 1958	3·6	39·9	1·8	4·80	5·4	44·5	99·0	—	26·2	—	0·75	0·10	13·5
Average	5·1	40·3	1·8	4·91	5·5	42·4	108·0	—	27·6	—	0·77	0·21	16·9
Soya Beans, Autoclaved, Defatted													
1. Sample received November, 1958	6·8	32·5	5·9	6·20	8·9	39·7	300·0	339	14·0	789	0·30	0·32	1·39
Butter Beans													
1. Autoclaved and defatted, November, 1958	7·2	20·6	1·4	3·96	6·0	60·8	142·0	216	8·0	425	0·27	0·11	0·95
2. Whole, received January, 1959	9·2	19·5	2·6	3·95	5·7	59·1	130·2	—	18·5	—	0·32	0·13	1·18

NOTE.—The following factors were used in estimating protein content: fish flour N × 6·25; groundnut flour N × 5·46; milk powder N × 6·38; soya beans N × 5·71; butter beans N × 6·25.

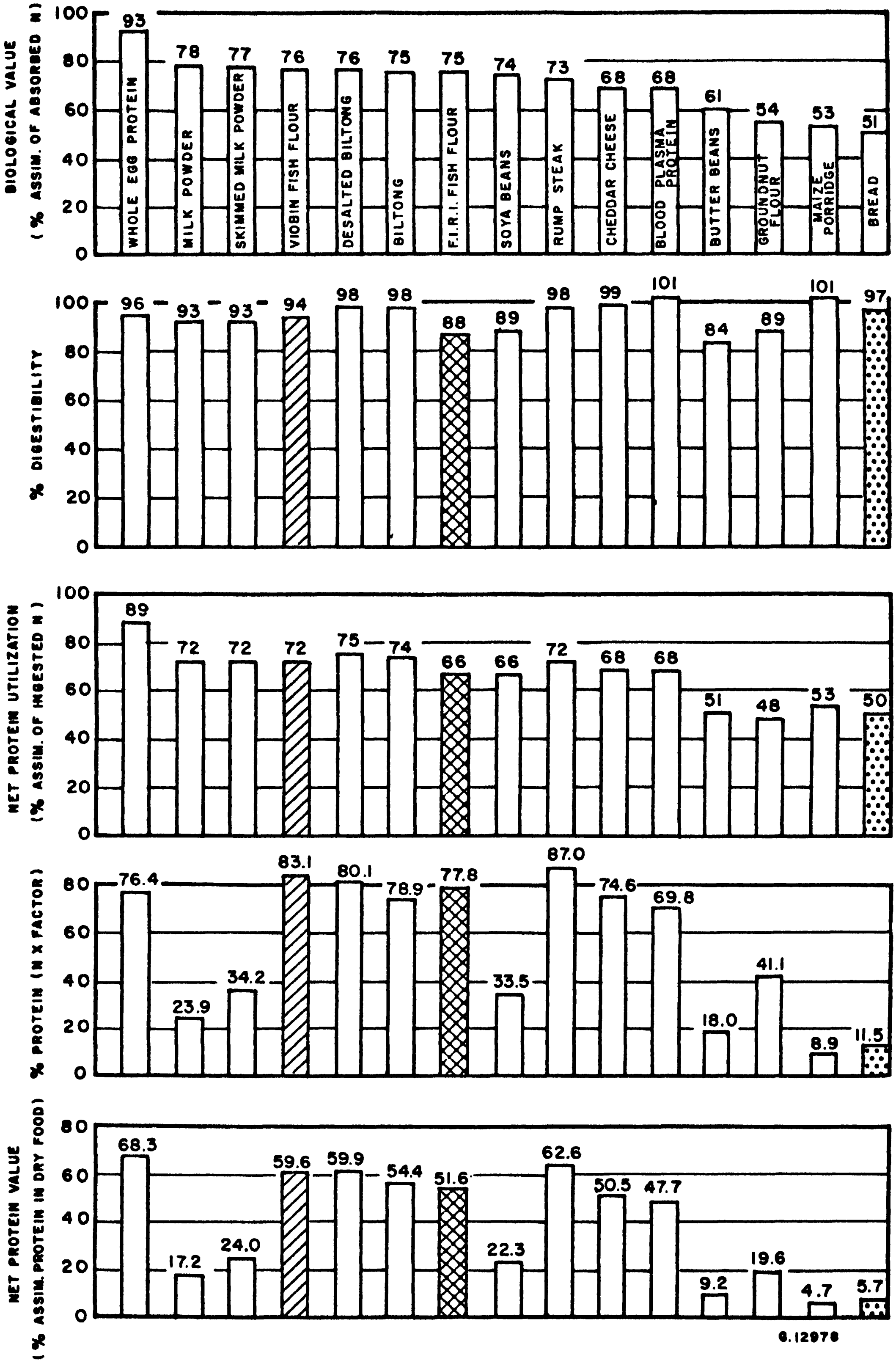

Figure 1 – Relative protein values of certain protein-containing substances (moisture-free basis)

(supplied by Dreyer)

manufacture of foodstuffs and the fish flour had to comply with the following tentative specifications:

1. 100 per cent of the fish flour to pass a 55-mesh standard Tyler Screen (0·0082 in. aperture).
2. To be free of all visible signs of mould, insect or other infestation.
3. Maximum moisture content 8 per cent.
4. Maximum fat content 0·7 per cent, by acid hydrolysis.
5. Minimum crude protein content of 75 per cent on a moisture- and fat-free basis.
6. Maximum ash content 25 per cent.
7. The biological value of the protein of the fish meal not to be impaired during extraction and drying.
8. Addition of 4 per cent, based on the weight of the dry ingredients, not to affect the colour or flavour of brown bread.
9. The flour to keep satisfactorily without reversion.

The nutritive value of fish flour.—(Experiments at the National Nutrition Research Institute, Pretoria.)

Chemical composition.—Comparison of chemical composition of samples of two types of fish flour, one prepared by an American company (VioBin), the other prepared in South Africa by FIRI, with certain other protein-containing materials is presented in Table I. These data indicate in general that fish flour is an outstanding source of protein and certain minerals, especially calcium and phosphorus, but by no means as outstanding a source of the other nutrients studied, with the possible exception of iron. As a result of solvent extraction the vitamin contents are reduced substantially below those present in fresh fish or fish meal from which the fish flour is made.

In addition, FIRI fish flour contained appreciably less potassium than the fresh fish from which it was derived. Fish flours of the types tested up to now at the NNRI cannot, therefore, be regarded as equivalent in nutrient content to fresh fish. They do, moreover, differ considerably in composition from cow's milk, a point which should be noted by nutritionists and pediatricians when considering possible foods other than milk for the prevention of kwashiorkor.

Bacteriology and toxicity.—Fish flour produced by solvent extraction following the FIRI process has a high degree of bacteriological purity when it emerges from the extraction. Preliminary studies on the growth, breeding performance, and histopathology of rats receiving a diet of 28 per cent of FIRI fish flour or certain control diets for a period of 199–203 days revealed no evidence indicative of the presence of toxic substances in the fish flour. Growth and histopathological studies on the second generation of rats bred from the above rats, and raised on the same diet for 87 days, also showed no evidence suggestive of toxicity.

The protein value of fish flour and its supplementary value in bread.—The relative protein values of certain protein-containing substances, including those of FIRI and of VioBin fish flour are shown in Fig. 1. These results were obtained in protein evaluation tests with rats by the nitrogen balance method. In view of the results which have been obtained, fish flour clearly occupies a favourable position with regard to protein quality and assimilable protein content. Reasonably small amounts of these and other animal products are capable of providing FAO's allowances of protein at all ages.

The results obtained for the relative abilities of certain supplements to provide extra assimilable protein when incorporated in 90 per cent extraction bread are shown in Table II. From a study of the figures given in the last column of Table II it can be seen that FIRI fish flour was much the best of the supplements tested as regards the ability to provide extra assimilable protein. It should be noted, however, that even at a level of supplementation of 4 per cent a large amount of bread would have to be eaten to provide sufficient amounts of extra assimilable protein to meet FAO's recommendations regarding levels of supplementation for children. The extent to which benefits could be derived from these contributions under practical conditions would depend on a number of factors; such as, the existence of a need for extra assimilable protein, the extent of the need, and whether the diet is adequate in other respects apart from its protein component.

The minerals in fish flour.—Fish flour contains appreciable amounts of various minerals, e.g., calcium, phosphorus, iron, magnesium, sodium, potassium, etc.; the total ash amounting to about 20 per cent.

A study was made of the weight gain, body length, femur length, femur ash content, liver iron content, and mineral balance of growing rats fed a diet in which FIRI fish flour provided the sole source of minerals, and of rats fed similar diets containing various added levels of a standard mineral mixture.

In general, the results indicated that under the experimental conditions employed, the minerals in FIRI fish flour were available for utilization by the rat but that the mixture of minerals was not a complete one. The results of further work indicated that the low potassium content was the limiting factor in the mineral composition of the fish flour.

Fish flour as a source of protein for kwashiorkor and convalescent kwashiorkor cases.—In assessing the value of fish flour as a protein supplement, consideration should be given to its ability to promote recovery from, as well as its capacity to prevent kwashiorkor, a disease widely regarded as a type of protein malnutrition, predominantly. In this connection, there are interesting results from experiments carried out to ascertain whether fish flour can be used to replace skimmed milk powder in the treatment of kwashiorkor in the convalescent stage. Two series of tests were made of this material as a feed supplement, one with a 40 per cent fish flour formula and the other with a 10 per cent fish flour formula.

On the basis of the results it would appear that the experimental diets containing 10 or 40 per cent of the FIRI fish flour used in these tests (expressed on the

TABLE II

The relative abilities of certain supplements to provide extra assimilable protein when incorporated in 90 per cent extraction bread (data based on nitrogen balance experiments on rats)

Supplement	*Number of Parts (by Weight) added to 100 Parts of 90% Extraction Rate Wheaten Flour*	*Added N as % of Total N in Mixture*	*No. of Rats used (equal numbers of males and females in all cases)*	*Gain in Assimilable Protein (g.) per Pound of Fresh Bread (moisture content 40%)*
SKIMMED MILK POWDER	0	0·00	8	0·00
(commercial; roller-dried)	4	6·65	8	2·35
	8	12·27	8	4·34
	12	17·18	6	6·08
SOYA BEANS	0	0·00	8	0·00
(autoclaved; ether-extracted)	2	3·20	8	1·14
	4	6·89	8	2·46
	8	12·59	8	4·49
	16	21·04	8	7·51
L-LYSINE HCl	0	0·00	8	0·00
(Du Pont)	0·1	0·73	8	1·85
	0·2	1·55	8	2·66
	0·4	2·67	8	2·68
	0·8	4·99	8	2·71
	1·6	10·93	8	2·80
GROUNDNUT FLOUR	0	0·00	8	0·00
(commercial; defatted)	4	9·35	8	1·63
	8	16·95	8	2·95
	12	22·41	8	3·91
FISH FLOUR (FIRI)	0	0·00	10	0·00
(composite sample prepared from 5 different batches)	1	4·97	10	3·24
	2	8·90	10	5·79
	4	14·00	10	9·12
PREMIX	0	0·00	48	0·00
(consists of groundnut flour, skimmed milk powder and calcium salts)	6·5	10·41	48	1·71

basis of the dry ingredients) had characteristics which rendered them unsuitable for the treatment of kwashiorkor in a considerable proportion of cases. The reasons underlying the unsatisfactory response to these fish flour formulae are not yet clear, and are still being investigated.

The samples of VioBin fish flour used in these tests were more satisfactory than those of FIRI fish flour in the treatment of convalescent kwashiorkor under the conditions of the tests. Formulae based on skimmed milk powder or casein have, however, been found to be uniformly satisfactory for the above purpose.

The *prevention* of kwashiorkor by the use of fish flour in diets has not as yet been investigated.

TECHNOLOGICAL DEVELOPMENTS IN THE UNITED STATES OF AMERICA

by

E. R. PARISER

The most outstanding, independent contribution of this country until today has been the development, by the VioBin Corporation of Monticello, Illinois, of a process of azeotropic dehydration and extraction of lipids from comminuted fresh fish. Plants are in operation capable of converting large volumes of fresh fish into fish flour. There have been developed some other types of fish flour and methods of producing it, a short description of which is given in the paper, but none of these processes has been developed beyond the pilot stage.

Eminent American scientists have greatly contributed to the fish flour project by studying the nutritive values of both fish meal and fish flour.

In 1957 UNICEF, in consultation with FAO, arranged for an investigation to be carried out by the Department of Food Technology of the Massachusetts Institute of Technology and in the course of these investigations the following processing methods were examined: vacuum drying of the comminuted fish suspended in oil; azeotropic dehydration and subsequent extraction with 95 per cent ethanol. The effect of process variables on the quality of the final product was investigated and the samples were then subjected to chemical, biological and organoleptic tests. The plans for further work concerning the development of fish flour are discussed.

DEVELOPPEMENTS TECHNOLOGIQUES AUX ETATS-UNIS D'AMERIQUE

La contribution la plus remarquable et la plus originale de ce pays jusqu'à ce jour a été la mise au point par la VioBin Corporation de Monticello, Illinois, d'un procédé de déshydration azéotropique et d'extraction des lipides du poisson frais broyé. Les installations en fonctionnement sont capables de transformer de grandes quantités de poisson frais en farine alimentaire de poisson. D'autres types de farines alimentaires et les méthodes correspondantes de fabrication ont été également mis au point; cet article en donne une brève description, mais aucun de ces procédés n'a été développé au delà du stade expérimental.

D'éminents savants américains ont apporté une contribution importante au projet de recherches concernant la farine de poisson, en étudiant la valeur nutritive de la farine brute et celle de la farine alimentaire.

En 1957, l'UNICEF, en consultation avec la FAO, a organisé une étude d'ensemble que le Département de Technologie Alimentaire du Massachusetts Institute of Technology s'est chargé de conduire; au cours de ces recherches, l'examen a porté sur les méthodes suivantes de fabrication: dessication sous vide du poisson broyé en suspension dans l'huile; déshydration azéotropique suivie d'une extraction à l'alcool éthylique à 95 pour cent. Les effets des variables de fabrication sur la qualité du produit fini ont été étudiés et les échantillons ont été soumis à des essais chimiques, biologiques et organoleptiques. L'article commente les programmes de travaux futurs concernant la farine de poisson.

ADELANTOS TECNICOS EN LOS ESTADOS UNIDOS DE AMERICA

La aportación independiente más notable de este país hasta la fecha ha sido el descubrimiento, por la VioBin Corporation de Monticello, Illinois, de un procedimiento de deshidratación azeotrópica y extracción de los lípidos de pescado fresco pulverizado. Existen instalaciones capaces de transformar grandes volúmenes de pescado fresco en harina de pescado. Se han estudiado algunos otros tipos de harina de pescado y los procedimientos de fabricación correspondientes, de los que se da una breve reseña en este documento, pero ninguno de los cuales ha sido puesto en práctica todavía.

Algunos eminentes investigadores americanos han contribuido grandemente al programa de estudios sobre la harina de pescado, estudiando tanto el valor nutritivo de la harina de pescado para el consumo humano como el de la harina de pescado para piensos.

En 1957, la UNICEF, en colaboración con la FAO, organizó una investigación para ser realizada por el Departamento de Tecnología Alimentaria del Instituto de Tecnología de Massachusetts, y en el curso de la cual se examinaron los siguientes métodos de fabricación: desecación al vacío de pescado triturado y puesto en suspensión en aceite; deshidratación azeotrópica seguida de extracción con alcohol etílico al 95 por ciento. Se examinó el efecto de las variables del tratamiento en la calidad del producto obtenido, y las muestras fueron sometidas a ensayos químicos, biológicos y organolépticos. Se proyectan ulteriores trabajos concernientes al empleo de la harina de pescado.

THE most notable contribution to fish flour processing in the United States is that of the VioBin Corporation, which is briefly discussed in this report along with other methods of which little is known. Nutritive evaluations of fish flour are noted and the results are reported in some detail of the UNICEF study to assess the effects of selected processing variables on the composition, protein quality, and organoleptic characteristics of fish flour. Finally, the objectives of future research contributions envisaged by the United States are detailed.

Development of processing methods

VioBin process.—The VioBin Corporation of Monticello, Illinois, developed a process of azeotropic dehydration and extraction of lipids from comminuted fish. The United States patent issued in 1945 (24) describes the production of a dried, defatted enzymatic material by using a chlorinated hydrocarbon in an azeotropic distillation. Essentially the same method is used in the manufacture of fish flour from fish. For the production of a deodorized and tasteless concentrate, the dehydration/defatting stage has to be followed by an extraction with another solvent such as methyl or ethyl alcohol.

The VioBin process (further patents 25, 26) has progressed beyond the pilot plant stage. The VioBin plant in New Bedford, Massachusetts, is in operation and capable of converting large volumes of fish into fish flour.

In contrast to almost all of the other processing methods that have been developed in this country, the engineering aspects of the VioBin process are well documented (9). A number of investigators have reported studies on the nutritive value of the finished product (4, 12, 19, 21, 29).

General Foods process.—The General Foods Corporation Research Center in Tarrytown, New York, has developed a method for the production of two types of fish flour, one water-soluble, the other water-insoluble. Little is known about the technical details of manufacture or of the nutritional characteristics of the end products.

Lever Brothers process.—This firm was granted a United States patent (28) for a process by which the English inventors, Galliver and Holmes, claim to produce an entirely odourless and tasteless fish flour. The process consists of comminuting freshly-gutted fish, mixing it with 1 per cent of its weight of sodium sulphite and sufficient aqueous sodium hydroxide to raise the pH to 10. The mass so obtained is drum-dried and the dried material extracted with acidified 95 per cent ethanol. At the completion of the extraction, residual alcohol is evaporated, the extracted material suspended in water, and the pH adjusted to 7. The material is filtered, washed with water, and finally tray-dried at 50°C. It is not known whether this processing method has been tested beyond the laboratory stage.

L. Mandell process.—In Providence, Rhode Island, a system has been devised of continuous counter-current solvent extraction in which meal or comminuted fish is processed in a battery of screw conveyors. The process is being patented and pilot-plant tests are planned at a fish meal plant in Gloucester, Massachusetts.

Vacuum dehydration.—Other processing methods include the vacuum dehydration at 40°–50°C of fresh fish with the help of a heat transfer medium (27). The comminuted material is slurried with a vegetable or other edible oil and subjected, with agitation, to vacuum dehydration. The material is thus rapidly dried, and oil and other lipids removed from the meal by suitable means. Final deodorization of the dry material is effected by extraction with a polar solvent. It is not known whether large-scale tests have been conducted with this method.

Evaluation of the nutritive value of fish flour

Allison, Scrimshaw, Harper, Huntley, and others studied the nutritive value of both fish meal and fish flour of different origins, and the results obtained indicating the possible value of fish flour are well known (18). The nutritional value of fish flours manufactured on a pilot-plant scale was recently studied by Caroline H. Kurtzman at the University of Maryland (7). The results include a review of previous work in this field and point to certain differences in the protein content and quality of fish flour manufactured according to various methods. The Bureau of Commercial Fisheries of the United States Department of the Interior has investigated the nutritive value of fish flour at the Bureau's Technological Laboratory at College Park, Maryland. Results in general have indicated that the protein quality of fish flour may be quite variable. An excellent review article on the use of fish flour for human consumption is that of Olden (14).

UNICEF study

In 1957, UNICEF through FAO, arranged for an investigation by the Department of Food Technology of the Massachusetts Institute of Technology to assess the effects of certain selected processing variables upon the composition, protein quality, and organoleptic characteristics of fish flour. The following processing methods were studied: vacuum drying of the comminuted fish suspended in oil; azeotropic dehydration, with 1,2-dichloroethane, and extraction of moisture directly with 95 per cent ethanol.

The effect of processing variables on quality was investigated by preparing, in a pilot-plant supplied by UNICEF, experimental fish flour samples using five different processes.

The results of this investigation can be summarized as follows:

(i) The various methods mentioned above for the dehydration of fresh fish were found workable on a small pilot-plant scale.

(ii) Under these conditions, ethanol will extract fish lipids extractable with hexane, as well as an appreciable amount not extractable with hexane. Successive extractions with hexane then ethanol may be slightly more efficient than with ethanol alone. The extraction with warm ethanol proceeds in two distinct phases. Initially the rate of solvent exchange in the extraction vessel controls the rate of extraction; thereafter, this is controlled by the solvent/meal contact time. During the latter state the size, shape, and porosity of the meal particles, as well as the solvent/meal contact time are important variables. Under otherwise identical conditions, the tendency to "fines" formation was greater with hexane than with warm 95 per cent ethanol.

The following experimental fish flours were prepared to evaluate the effect of certain process variables on product quality:

Fish flour 1: Prepared from commercial Chilean Merluzza (hake) presscake meal by successive extractions with commercial hexane and ethanol.

Fish flour 2: As flour 1, but extracted only with ethanol.

Fish flour 3: As flour 2, but given an acid soak and treatment with alkaline alcohol before final extraction.

Fish flour 4: Prepared from fresh fish by dehydration with ethanol with further treatment as for flour 3.

Fish flour 5: Prepared from fresh fish dehydrated azeotropically with 1,2-dichloroethane, and extracted with methanol.

The following observations were made of these flours:

The protein level in the flours was higher than in the respective raw materials due to removal of non-protein components during extraction. Highest in protein was flour 4, which also showed a higher percentage of lysine in the protein than any of the other flours. Next highest in protein was flour 5, but the methionine content of this flour appeared to have suffered some damage. There was little difference between flours 1, 2, and 3 in protein content and amino acid make-up. There was no significant difference in the nutritive quality of the protein between the 5 experimental flours when used as the sole source of protein in rat feeding studies. All flours gave markedly better growth than the casein control diet.

All flours smelled faintly of fish, flours made from commercial meal slightly more so than those made from fresh fish. At 5 per cent of the wheat flour used, all fish flours gave fairly acceptable breads, although loaf volume and crumb colour were affected. Breads made with flours from fresh fish were judged to be fairly acceptable also at the 10 per cent level of addition. Flour 1 gave slightly better results than flours 2 and 3.

Future contributions

Examination of information available on fish flour manufacture clearly points to the fact that a great deal of work must be done to ensure that a cheap product of high nutritive value can be produced from different species of fish. The Bureau of Commercial Fisheries of the United States Department of the Interior has recently initiated a program for further development of this important food product.

It is planned that all available information regarding the manufacture of fish flour will be collected and studied by staff of the Bureau and by an advisory group of experts in various scientific disciplines. Based on these findings and technical advice it will be attempted to design and fully test one or several processes that will:

(*a*) require low initial capitalization;

(*b*) be economical in operation;

(*c*) be flexible for large and small-scale production;

(*d*) be flexible to permit operation in those parts of the world where public utilities are limited;

(*e*) be flexible to permit the manufacture of a product that will be accepted by people who may have varying taste preferences, cultures, and taboos;

(*f*) result in the production of a consistently uniform high-quality protein concentrate;

(*g*) result in the production of a product that could be cheaply shipped to distant parts, could be stored for varying periods without quality loss and that could easily be incorporated into the local diets of undernourished people.

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DISCUSSION

Mr. F. E. Popper (FAO): Taylor's comment that the market for fish in the more developed countries is in a static condition is misleading. Use of national averages is dangerous. The analysis of the different groups that make up the national averages shows that the consumption is not static, but varies with groups. Much could be done to improve this static condition by the production of new fishery products. In general, however, developing countries have more opportunity for increased consumption of fish products.

Mr. D. L. McKernan (U.S.A.): I agree with Popper. The note of pessimism regarding drop in fish consumption with increase in income is not justified. The situation is too complicated to warrant the assumption that an improved standard of living brings about a decreased use of fish. The need for protein may not be met by meat. Fish is probably a more economical source of animal protein than meat. Reports from developing countries indicate the great need for fish for human food. Fish is available in many tropical areas where animals cannot thrive.

Mr. H. Loredo (Mexico): In discussing fisheries, processing must be considered as well as production proper. In Mexico dried fish was given priority, since it synthesized the solution of the problems inherent in the handling and distribution of such fish products. To show interested manufacturers the possibilities of expanding their operations and to include other species of fish than at present commercially used, it is intended to establish a centre for technical research and demonstration for the drying of marine products on the northern Pacific coast. It is obvious that this or any fishery development policy is something more than a combination of natural resources and technological methods of exploitation. Fish and fishery products have economic value, because they satisfy a market demand.

Dr. J. van Mameren (Netherlands): Canning of lean fish has often been tried unsuccessfully in western European countries. This failure is not a matter of quality, but a lack of demand for the product. When producing for the tropical market, we should keep in mind these consumers who may not be too enthusiastic about new foods. Food technologists should bring to these people a product that satisfies their preference for certain flavours and tastes. With this in mind, we are now successfully introducing new fishery products. The decreasing fish consumption in western countries is due to inferior quality, as compared to other protein-rich foods, meat and dairy products. These foods are handled more carefully, with more attention to quality. Poor handling and preparation result in fishery products often being rated as second-class food.

Dr. R. A. Taylor (U.K.): Marketing is the most important problem. Producers of fishery products have a great deal to learn about the problems of trading. In regard to Mr. Popper's criticism of my statement on income elasticity in developed countries, I realize there are differences between income groups. My generalization was based on the assumption that the effect of any increase—with improved living standards—in the consumption of "luxury" type of fishery products would be likely to be cancelled out by a drop in the consumption of "inferior" products, i.e. fishery products characterized by negative income elasticity.

Dr. R. Kreuzer (FAO): Marketing is very important also in the developing countries. New products must have consumer appeal. In Tunisia a new product was refused because it was unfamiliar to potential consumers. A fishery product adapted to Tunisian habits was developed and was readily accepted. Fishery product technology must go hand in hand with economic considerations.

Dr. G. Varela (Spain): The demand for fish will increase in developed countries as well as in the developing countries. There is a relationship between increased income and fish consumption, but not between expenditures for food and for fish. Correlation coefficients of 0·57 and 0·04, respectively, were found for these relationships in Granada, Spain. Many other factors in addition to income are involved in determining demand for fish.

Dr. G. M. Dreosti (South Africa): More than most people realize, consumption depends to a great extent on the quality and uniformity of quality. Experience in improving pickled fish confirmed this in South Africa. A great increase in demand resulted when the quality of this product was improved and maintained.

Prof. B. C. Guha (India): The fishing industry in developed countries may be marginal, but in developing countries fish consumption is capable of considerable expansion. In some areas the rise in fish consumption is limited by the availability of fishery products or by the price of the commodity. In areas where there is a limited market for fish, the consumption can be increased by improved quality and distribution. In many areas the establishment of cooperatives may help to eliminate monopolies, decrease prices and increase fish consumption.

Dr. R. Kreuzer (FAO): Increasing living standards will not necessarily increase fish consumption. Fish products must be marketed in a form that appeals to the consumer. Efforts should be made to develop new products or variations of existing ones. In Japan, where fish consumption has been the highest in the world, a trend from fish to meat has accompanied an increase in the standard of living. To combat this trend a fish sausage, with a meat flavour and no fishy odour, was developed. This has high consumer acceptance and substitutes for meat which is too expensive for the average citizen.

Mr. C. Butler (U.S.A.) summarized the status of fish flour processing research as a basis for the discussion.

Dr. A. G. van Veen (FAO): Why did FAO attempt to promote fish flour? Dried salt fish, even though very cheap, does not keep well. It was thought that fish flour might offer the following advantages: (1) can be cheaply produced, (2) can have high nutritive value, (3) can be stored without deterioration, (4) does not require special containers, cheap to transport, and (5) acceptable to various population groups. Work has shown that, in addition to technological problems, such as nutritional loss in processing, variations in batches and consistency, fish flour also has acceptance problems. FAO has tested fish flour throughout the world, in 25 to 30 countries both developed and developing. On the basis of these tests, it is suggested that the following should be carried on: (1) a determination of the acceptable uses of fish flour; (2) research and marketing; (3) promotional campaigns and education. The whole programme may meet failure, if such studies are not done.

Dr. J. A. Lovern (U.K.): At the International Fish Meal Conference in Rome, the main result of the meetings of fish flour "Committee B" was the development of recommendations regarding specifications for fish flour types A and B; defatted and non-extracted products respectively.

Dr. M. Milner (UNICEF) reported on the activities of the fish flour plant in Chile. In 1958 the Chilean plant first made fish meals and fish flours. Difficulties were encountered in the processing of fresh fish. The operations stopped; the difficulties remedied; and operations reopened in mid-1961. A number of experimental runs were made, in which the dried fish were extracted with hexane, ethanol, or both. The following data are typical analyses of fish flours extracted with these solvents.

	Solvents	
	Hexane	**Ethanol**
Moisture	8·25	7·62
Fat	1·16	0·76
Crude protein	79·95	78·63
Ash	14·73	16·59
Lysine	7·87	8·40
Acid insoluble ash	0·19	0·19

The acceptability of these products is being tested in school-feeding schemes in Santiago, Chile.

Mr. R. Meesemaecker (Morocco): Morocco was one of the first to produce fish flour and conduct large-scale acceptability tests in hospitals and schools. The flour was also sold in stores and used in medical studies. Since the potential production exceeds the country's needs, Morocco could export fish flour if demand existed. Fish flour, however, is not the most important protein resource, for dried, smoked, canned and frozen fish are important protein foods and have ready consumer acceptance in this and other African countries. Canned sardines, tuna, and other species are exported throughout the world and contribute greatly to maintaining a protein balance in the African countries. Morocco has also developed a high protein fish paste that is very acceptable to Africans. All these products can be improved by studies of quality and preservation methods. It is recommended that FAO does not overlook the conventional means of fish preservation in future research. Total effort should not go to fish flour studies.

Dr. C. L. Cutting (U.K.): Ten years ago, the first FAO conference on fish processing technology, in Bergen, set up four working groups, one of which was on fishery products for tropical areas. After reporting to the Rotterdam Conference in 1956, this group was inactivated due to insufficient funds. The group should be reactivated to assist FAO in overcoming the gap revealed in this Conference between technology research in member countries and its application in developing countries. It is recommended that at least one new fish technologist should be added to FAO's Fish Processing Section especially to maintain contact with members of the working group, agencies and governments.

Mr. D. L. McKernan (U.S.A.) asked if Dr. Cutting suggested reactivating the original committee or did he propose to broaden the group.

Dr. C. L. Cutting (U.K.): In view of the widespread interest in the subject, membership of the working group should be broadened accordingly.

Mr. C. Gonzales (FAO): Each country should develop its own processing techniques for fish flour. The fish flour should not only be tested for protein quality, but for keeping quality during storage and transportation. Consumption of fish flour by humans could be dangerous, especially in tropical areas, unless there are adequate controls of the product quality. The economic status of a country will determine when the studies of fish flour processing will be started. In the meantime, efforts should be made to improve the methods of salting and drying fish. We must keep in mind that at present 25–40 per cent of the people in developing countries eat salted dried fish. In tropical countries in urgent need of improvement of nutritional standards, this type of product can be developed as a "cottage industry" in which the "processors" salt and dry the fish in the sun.

Dr. B. Hallgren (Sweden): There is no prohibition in Sweden against the use of whole fish in fish flours, which are sold as such. However, this delegation is still not certain that fish flours made with chlorinated hydrocarbons are safe and non-toxic. This has still to be proven.

Mr. H. Loredo (Mexico): Several Mexican plants produce fish meals, but only meet about 40 per cent of needs. Most imports come from Peru. Because of the tremendous fishery resource and processing advances made in Peru, it is suggested that one of the fishery technological centres that I recommended should be created by FAO to train personnel might be located in that country.

Mr. C. Pautzke (U.S.A.): Old methods for preserving fish must not be overlooked in the development of new methods. Canning is still a good method. Since canned products are widely used and accepted, their costs are reduced and, as a consequence, canned fishery products reach many peoples of varying incomes. Nowhere in universities, industries, or governmental agencies do we have studies on the nutritional evaluations of all types of fishery products, especially for humans. United States and FAO should be encouraged to study nutritive value of fishery products for humans.

Mr. J. M. Gardiner (U.K.): There are ample supplies of high-quality raw material for fish flour. In U.S.A., menhaden from refrigerated boats are available, while in Norway, Peru, and South Africa the fish are taken in cold waters and/or very near the coasts so that fish reach the plants in good condition. Whitefish offal also is handled rapidly so as to be a good raw material. Many plants are already able to meet specifications for type B flours and existing plants could supply world needs for some time ahead. More difficult problems are likely to be financial and educational. However, since many of the leading scientists are members of the association and advisers to their country's meal industry, FAO can count on the utmost cooperation of the industry. Fish flour is already being processed in the United States by an azeotropic process, and a pilot plant is being erected by a menhaden company. To succeed in the developing countries, a programme of education is needed, and foods must be developed that are not only good nutritionally but have acceptable flavours. The Fish Meal Manufacturers Association looks forward to further discussions with FAO and with Bureau of Commercial Fisheries representatives at the coming conference in Lisbon.

Mrs. C. H. Kurtzman (U.S.A.): Fish flour must not only be acceptable in flavour and colour, but also in texture. At present it does not disperse well in liquids or in a baked product. It is gritty, and during baking there is often a release of volatile substances which are not pleasant.

Dr. D. G. Snyder (U.S.A.): We should clearly distinguish between market acceptability of fish flour and the nutritive quality of the protein. Dr. Combs cautioned us that we are not talking about protein, as such, but amino acids—and especially the presence of the amino acids needed to upgrade the vegetable proteins. Therefore, a process that will produce a consistently high quality protein is more important now than studies in acceptability and marketing.

Dr. G. M. Dreosti (South Africa): No toxic residues were found when ethanol was the extracting solvent. More work should be done to develop a product lighter in colour and finer in texture.

Prof. B. C. Guha (India): Mixing fish flour with other substances will camouflage the grittiness, and other ways may be found to increase acceptance by moulding mixtures in conventional shapes.

Dr. G. M. Dreosti (South Africa): Morocco now makes a neutral fish flour with 0·1 per cent residual fat. If there is more than 0·1 per cent fat, there is a reversion of flavour. It costs very little, however, to make an extraction so as to reduce fat content below 2·5 per cent. Three classifications of fish flours are suggested: Class A—less than 1 per cent fat; Class B—present Class A; Class C—present Class B.

Dr. H. L. A. Tarr (Canada): proposed that FAO hold a symposium covering the significance of fundamental research in successful utilization of fish to be used as a basis for technological development. He would further recommend that the symposium include reports from laboratories concerned with chemical, biochemical, physiological, microbiological and nutritional research.

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